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Journal of the  
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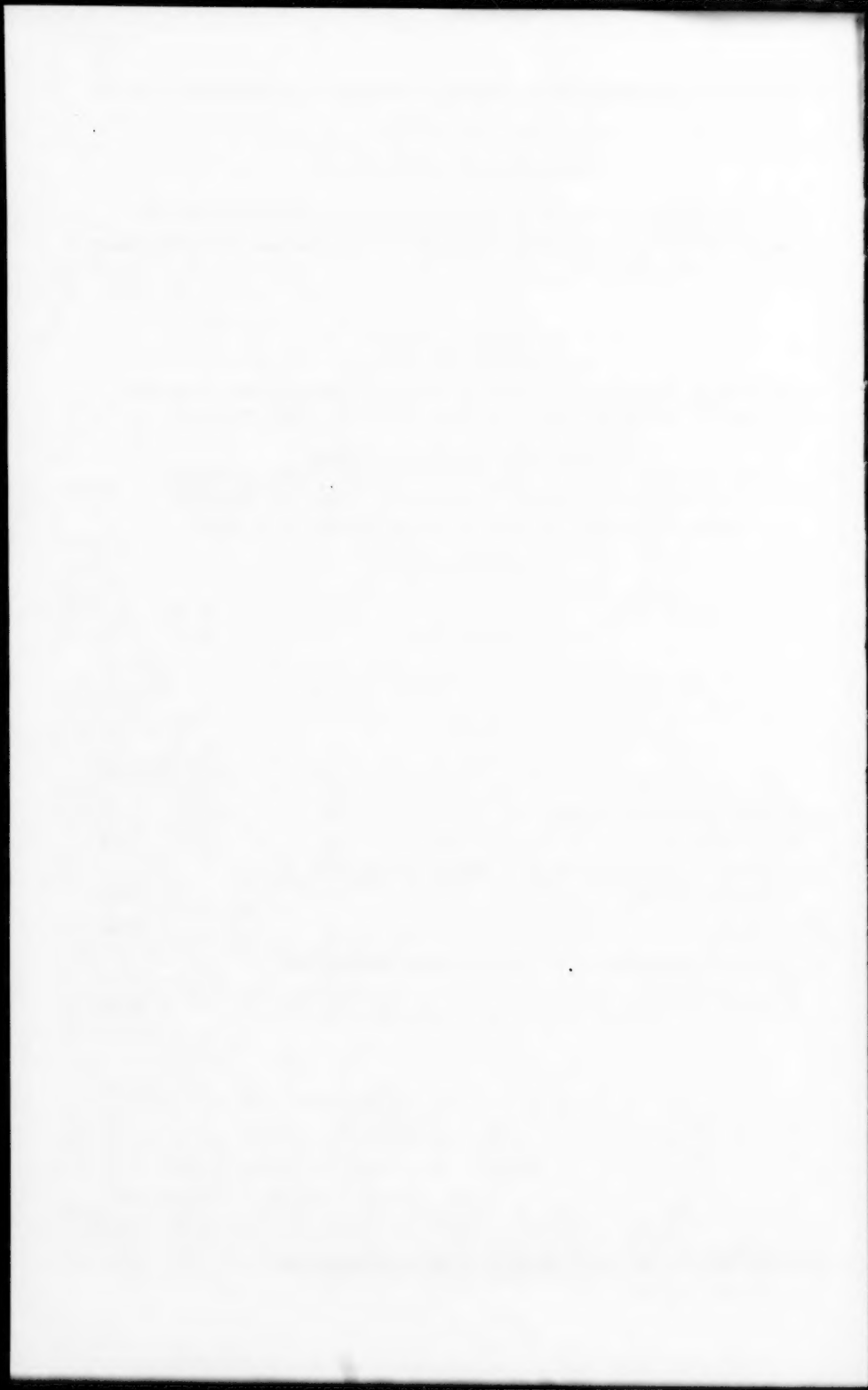
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ROAD DEVELOPMENT IN ONTARIO<sup>a</sup>

W. J. Fulton<sup>1</sup>  
(Proc. Paper 1524)

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ABSTRACT

In the 1957-58 fiscal year Ontario is spending an all-time high of \$234,315,000 on provincial highways and on subsidies for municipal roads and streets. Results of an engineering study which estimates highways needs for the next 20 years are given in brief. Organization of Department of Highways is outlined.

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Centrally located in Canada with one-third of the nation's population, producing one-half of the nation's manufacturing output, and richly endowed with natural resources, Ontario now has a population of 5,500,000. By 1975, an increase to 8,200,000 is expected.

Ontario has an area of 413,000 square miles, which is approximately equal to the combined area of all the New England States, New York, New Jersey, Pennsylvania, Ohio, Michigan, Indiana, Illinois and Wisconsin. From east to west it extends through 21 degrees of longitude across the Northern States from New York to Minnesota. From Lake Ontario and Lake Erie, it extends 1,000 miles north to the salt waters of Hudson Bay.

In Southern and Southwestern Ontario, along the shores of Lake Ontario, Lake Erie and Lake Huron, are plains covered with silt deposits left when the St. Lawrence outlet was blocked with ice at the end of the glacial period. These plains are now flat to rolling with a peak elevation of 1,700 feet above sea level. This southern section of the province is ideally adapted to both industry and agriculture but represents only seven per cent of the area of the province. It is there that four-fifths of the population is concentrated.

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- a. Paper presented before the Highway Division, American Society of Civil Engineers, June 4, 1957, Buffalo, N. Y.  
1. Deputy Minister of Highways, Ontario.

The metamorphic rocks of the Precambrian shield underlie all of Northern Ontario and extend south to a line between Georgian Bay and the east end of Lake Ontario. This is a rugged country, rich in minerals, densely forested and suited to agriculture only in limited areas. Dotted with lakes and scored by great rivers, it is still a sparsely settled land except where thriving industrial centres have become established chiefly with the development of natural resources such as timber and pulpwood, and rich deposits of iron, nickel, uranium, gold and other minerals.

The great disparity in population and in area, between Southern and Northern Ontario, poses unique problems to the highway engineer. The densely settled southern region, with its large cities and concentrated traffic volumes, requires and can support a closely-knit network of modern highways. But the balance of the population, widely dispersed over the vast expanses of Northern Ontario, must also be provided with road services.

From Ottawa on the east, to Kenora on the west, the distance by highway is 1,250 miles. The extremes of climate in Northern Ontario, the thinness of soil cover over hard granitic rock, the profusion of lakes that must be skirted or crossed, and the wet muskeg areas of the clay belt, all create exceptional road building difficulties. In many cases, settlement and economic development follow directly on the establishment of new routes, so that expenditures on road construction in the northern areas of Ontario, may be regarded as a long-term investment in the future. As a result, some 45 per cent of the provincial highway system of the province will be located in Northern Ontario.

#### Growth and Extent of Ontario Highway System

The Department of Highways in Ontario was first established in 1915 and by 1920 some 1,600 miles of county and township roads in Southern Ontario had been assumed as provincial highways. In 1930, these roads were named King's Highways. Roads in the north were under the jurisdiction of the Department of Northern Development until 1936, when all provincial roads in the province came under the authority of the Minister of Highways.

In total, we have over 83,508 miles of rural highway and urban streets throughout the province on all of which the province contributes either in whole or in part.

The Department is now responsible for 8,691 miles of King's Highways and 2,362 miles of Secondary Highways throughout the province. There are also 64,533 miles of rural road under the jurisdiction of the municipalities and districts and another 7,922 miles of urban streets.

#### Federal - Provincial Relations

In Canada, the responsibilities of the Federal Government and of each of the ten provinces are established under the British North America Act of 1867. It can be said that the Legislative Assembly of each province, acting within its legislative field, is a sovereign power with absolute authority over its territory and the people and property within it. This authority includes the rural highway or road system within the province, and, with one notable exception, the King's Highways of Ontario have been financed entirely out of provincial revenues for many years.

This exception is the Trans-Canada Highways project which was

authorized in 1949 and established by agreement between the Federal Government and the several provinces. The Ontario section of the Trans-Canada is some 1,410 miles in length from the Ontario-Quebec border, to the Ontario-Manitoba border. Ontario recommended the location of this highway, part of which will follow existing highways while other parts are now under construction through wilderness areas on the north-eastern shore of Lake Superior. All planning and construction of the Trans-Canada in Ontario is the responsibility of the Ontario Department of Highways which will also maintain this highway as part of the King's Highway system when it is completed.

The Federal Government established minimum standards which will apply in all provinces and contributes 50 per cent of the cost. The present agreement with the Federal Government will terminate on March 31, 1961, and every effort is being made to complete the Ontario section of the Trans-Canada by that date.

### Provincial - Municipal Relations

Over the years, the provincial government has made increasing funds available through subsidy for the construction and maintenance of municipal roads and streets in the province. These subsidies are administered by the Municipal Roads Branch of the Department and will total \$60,000,000, this year, or just over one-quarter of the Department's total budget.

There are some 1,400 municipal units in Ontario ranging from the great metropolitan area of Toronto, with over one and one-quarter million people, to unorganized units with a small and scattered population in remote areas of the province. Provincial subsidies vary according to the type and need of the municipal unit—33 1/3 per cent for streets and bridges in the cities, 50 per cent for roads and 80 per cent for bridges in the towns, villages and counties, and the amounts varying from 33 1/3 per cent to 80 per cent for roads in townships, improvement districts and Indian reserves.

All roads and streets in organized municipalities are under the authority of the municipality, although the Department reserves the right to determine whether subsidies will be paid on different projects and emphasis is placed on the desirability of capital expenditures rather than paying for maintenance on sub-standard municipal roads. On average, the province pays slightly more than half of the total road and street expenditures made by the municipalities.

### Current Expenditure Pattern

During the present fiscal year, which began on April 1st, our total estimated expenditure, including municipal subsidies, is \$234,315,000 as compared with \$203,800,000, and \$165,000,000, in the two preceding fiscal years. Each of these totals represented a new peak for the Department and it is expected that still further increases will be needed to take care of future requirements. We are now spending more in one year than was spent during the eight years, 1939 to 1947, inclusive.

In summary, the current budget provides \$121,734,000 for new construction on King's Highways; \$50,396,000 for maintenance and administration; \$60,000,000 for subsidies on construction and maintenance of municipal roads.

All expenditures are made out of the consolidated revenue fund of the province.

Revenues from motor vehicle registrations, drivers' license fees, gasoline taxes, etc., do not accrue to the benefit of the Department of Highways but are paid into the consolidated revenue fund. Over the long term, highway expenditures have been about equal to highway revenues, although there have been notable exceptions and we are now in a period when expenditures exceed receipts. I might say at this point that there are no toll roads in Ontario.

### Road Development and Needs

Until quite recently the development of Ontario's highways has not followed any long-range plan. Highway construction has been affected by wars and economic depressions and while there was a sharp rise in the scale of expenditures during the late 1930's it was followed by a period of retrenchment that continued during the war years when operations were confined to only the most necessary maintenance.

During the late 1930's the Department planned and constructed what is known as the Queen Elizabeth Way, the first modern four-lane, controlled-access, divided highway in the province, to link the Niagara border with the City of Toronto. In the past ten years, some 220 miles of four lane, divided, controlled-access highway has been constructed of which some 167 miles forms part of Number 401, which will extend for 505 miles across the southern part of the province to link Windsor, which is just across the border from Detroit, with the Quebec border.

Another modern highway, Number 400, extends for more than 50 miles north from the Toronto By-Pass section of Number 401. It is possible, therefore, to cross the Niagara border at Fort Erie or Niagara Falls, and travel some 160 miles by divided, controlled-access highway well into the part of southern Ontario that is central to some of our finest summer resort areas.

### Highway Needs Study

While these highways are very essential, they were not constructed as part of a long range over-all plan, and, since Ontario's growth in population, production and prosperity during the post-war years has been at a rate exceeding that of other sections of Canada and most of the United States, it was thought some estimate of our future growth was necessary. This study indicates that the average travel per vehicle will increase from 8,750 miles in 1956, to 9,500 miles in 1975, and that there will be one vehicle for every two persons in 1975, as compared to one vehicle for every 3.2 people in 1956. It is predicted that there will be three times as much traffic in 1975 as there was in 1955. Faced with these figures, it was apparent that it was necessary to study our highway problems objectively and plan a long-term program that would keep pace with the growth of our expanding economy.

As a result, an engineering study of our entire King's Highway system was made; a report has recently been issued under the title of, "A Plan for Ontario Highways." Throughout this study, which was conducted by Department of Highways personnel, most valued assistance and advice came from the Automotive Safety Foundation. The Department gained much from their experience in carrying out such studies in the United States.

One of the main steps in this study was to create a functional classification plan, grouping those routes that are properly the responsibility of the province on the basis of service performed. With this plan as a foundation, a necessary degree of stability can be achieved in estimates, programs, finances and organization—granting that changed conditions infrequently may require minor adjustments. Moreover, it will facilitate the primary aim of insuring that the King's Highways provide a consistent level of service throughout the province and its subdivisions.

The selected King's Highway system, totalling 8,600 miles, include these three major classes:

1. Freeway Highways - totalling 800 miles of the most heavily travelled routes, connecting metropolitan centres and serving as the backbone facilities for interprovincial and international movement. This class carries 32 per cent of King's Highway travel on nine per cent of the system mileage.
2. Trunkline Highways - totalling 4,920 miles of routes handling relatively large traffic volumes and linking other big cities and important areas of the province. This class carries 50 per cent of the travel on 57 per cent of the system mileage.
3. Feeder Highways - totalling 2,800 miles of routes that, while not significant from the standpoint of system interconnection, provide a desirable level of accessibility to King's Highways in rural areas and, at the same time, serve numerous smaller communities. Feeder highways carry the remaining 18 per cent of the travel on 34 per cent of the mileage.

On the basis of this proposed system, a factual engineering appraisal of needs was prepared. The backlog of existing deficiencies was determined by evaluating highways, roads and streets, against standards in line with experience and conditions found in Ontario. Deficiencies accruing within the next 20 years were determined with reference to estimates of traffic growth and the service life of present facilities. No road now affording at least tolerable service was listed as currently inadequate.

#### Cost of Improvements

Capital needs through 1976—on the classified King's Highway system and other roads under provincial jurisdiction—add up to \$1.9 billion. Of that amount, \$782 million would go for backlog work needed now on 5,400 miles. Including maintenance and administration, the aggregate cost is \$2.7 billion at 1955 price levels; municipal subsidies are not included.

Some 16 per cent of the aggregate cost, including maintenance is for Secondary Highways and other roads for which the province is responsible.

About 60 per cent of King's Highway construction costs are related to construction of 1,820 miles of multi-lane highway that should be built within 20 years. More than 620 miles of them are sorely needed now. It should be noted, however, that 75 per cent of the King's Highway system will still remain two-lane roads in 1976.

Especially significant is the fact that King's Highway system total costs average 0.88 cent per vehicle mile over the future 20-year period, as compared with 1.3 cents in the past 18 years; per vehicle costs would total \$36 annually, as compared with \$46 in the past.

### Alternative Programs

Naturally, it is desirable to eliminate the accumulated highway deficiencies as soon as possible, but it would be wholly impractical to attempt to get the job done in a year or two.

Rather, the catch-up work must be spread out over a period of years, during which new needs will arise from increasing traffic demands and the wearing out of pavements. During this time, too, maintenance and administration will continue.

As a basis for legislative decision as to how fast it is feasible to carry forward the work contemplated in the report—and how much money should be spent each year—three alternatives are suggested: a catch-up period of 10 years, another of 15 years, and another of 20 years.

Over 20 years, total expenditures would be nearly the same whichever program was selected, but of course, the valuable benefits of improved roads would be available much sooner with a shorter catch-up period. Best for the province would be the 10-year period. This year's budget figures out at a catch-up period of about 16 1/2 years.

### Administration, Organization and Methods

To carry out this work, there are 11,000 employees in the Department of Highways, 75 per cent of whom are located in 18 district offices. There are 276 professional engineers and 2,395 engineer's assistants, who comprise nearly one-quarter of the total staff.

This Department is organized in seven branches under the Minister, who is a member of the provincial cabinet, and the deputy minister who acts as his advisor in matters of policy and administration. At the present time, control is very largely centralized at head office in Toronto but it is the plan to decentralize and place more responsibility on regional offices which will be closer to local conditions in the various districts.

The chief engineer, the director of services, the director of personnel, the financial comptroller and the chief engineer of municipal roads, all report directly to the deputy minister. The director of planning and design and the manager of operations, report to the chief engineer.

Under the director of planning and design, there is the economics and statistics section, the priorities section, the location section, the traffic section, the soils section, the road design section and the bridge design section. They make all investigations and prepare estimates and designs prior to calling the contract.

Under the manager of operations, there is the contract section and the eighteen districts who are responsible for the construction and maintenance of the highways.

The services branch administers the purchase, sales and rental of all departmental property and makes property surveys for acquiring title to land. This branch has a wide variety of functions, including purchase of all materials, maintenance of department vehicles and control of district stores of maintenance and construction materials.

The municipal roads branch administers legislation with respect to municipal roads and streets and supervises the allotment of subsidies. A municipal engineer is stationed in each district.

In addition to these four operational branches, there is a personnel branch

and, of course, the financial comptroller's branch. Operating at the present time directly under the Minister, is the motor vehicles branch\* which supervises the issuance of motor vehicle permits and drivers' licenses, compiles accident statistics, conducts safety campaigns and administers the financial responsibility provisions of the Highway Traffic Act.

### Engineering Personnel Problems

With the increasing tempo of our construction program, requirements for graduate engineers and engineer's assistants are greater at this time when there is also a strong demand for engineers from private industry and other governmental agencies. While starting salary rates compare favourably with salaries offered to recent graduates from Canadian engineering schools, the Department is having difficulty in filling our requirements and is taking action to improve the situation.

One step which has been taken to augment the staff was to send three representatives to the British Isles where they succeeded in recruiting 60 engineers and 20 draftsmen who are being absorbed into our organization.

In order to release some of our present staff for other work, the Department is using electronic equipment to compute earth work quantities and other repetitive operations.

The Department has initiated special training courses and on-job training for department personnel which are designed to up-grade engineer's assistants to posts of greater responsibility. In addition to a small permanent staff of teachers, the students receive lectures from department engineers. Arrangements have also been made for a course in highway technology at the Ryerson Institute of Technology in Toronto. It is hoped to attract to this course graduates of secondary schools who are unable to take the longer university course in engineering.

While it is our policy to do as much as possible of our own design, the increased volume of work and resultant shortage of staff, has made it necessary to use the services of consultants. At present, some 10 per cent of our road design and investigation work, and 65 per cent of our structural design is being done by consultants.

Until quite recently, there has not been a post-graduate course in highway engineering in any Canadian university. During 1956, we started a joint highway research project with the University of Toronto and Queen's University. This is patterned after the research project at Purdue University and it is expected that this program will assist us in some of our technical problems and, at the same time, enlist the interest of graduate engineers in highway engineering as a profession.

### Contractor Relations

Practically all construction is done under contract with the department supplying some materials, such as cement, asphalt, reinforcing steel, etc. Award of contract is made to the lowest bidder and sealed tenders are opened

\* Editor's Note: Effective July 1, 1957, the Motor Vehicles Branch and its functions were transferred from the Department of Highways to the newly-organized Department of Transport. The Honourable James N. Allan, Minister of Highways, has also been designated Minister of Transport.

in public. Over the past two years, a number of procedures have been introduced which are to the mutual benefit of the department and the contractors and there is no dearth of bids for department jobs. Quite recently two new procedures have been introduced to insure that large contracts will be completed on schedule. On top priority projects we are inserting a liquidated damages clause which provides that the work must be done within a stipulated time, after which the additional cost of the department's supervision will be charged to the contractor. On larger jobs, we are introducing a system of prequalification of contractors to make sure that contractors who are permitted to bid are financially and technically capable of performing the work.

Under the Highway Improvement Act, the Department is empowered to pass regulations controlling development abutting the King's Highways. Any proposed structure within 150 feet of the highway limit, must have a permit from the Department and traffic generators such as shopping centres, outdoor theatres, etc., are required to get a permit if they are within one-half mile of the highway limit.

The signs on buildings are restricted both as to size and number and field advertising signs must be at least 1,000 feet apart and they have to have a permit, for which a fee is charged. They are permitted at varying distances from the right-of-way limit, depending on their size.

Another fact of interest is our ability to obtain new legislation quickly as needed. Under our system of government, if legislation sponsored by the government is defeated, that constitutes a vote of lack of confidence and the House is dissolved and an election is necessary.

### CONCLUSION

Looking back over a life-time career of planning and building highways in Ontario, I am convinced that we now know more of what our future highway requirements will be and we are better organized to fulfill the need, than ever before. Long-term planning is vitally essential to a modern highway program, and in order to get production on an assembly line basis, we think that an approved program for at least four or five years ahead is necessary in order that all the essential traffic studies, design problems, property acquisitions, moving of services, etc., can be scheduled and carried out well in advance of the calling of the contract.

The plan that has been completed will be kept up to date; in another two years a supplementary plan will be available which will cover all of the municipal roads and streets in the province. Only with modern highways can we hope to continue the economic development of our countries and this will require the best efforts of all of us who have made highway engineering our profession.

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ADAPTABILITY OF INTERCHANGE TYPES ON INTERSTATE SYSTEM<sup>a</sup>

Jack E. Leisch,<sup>1</sup> A.M. ASCE  
(Proc. Paper 1525)

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SYNOPSIS

Selecting the proper type of interchange for various crossroad conditions is the first and perhaps the most important step in design. This paper recommends types of interchanges based on analyses and comparisons of operational features and capacity potentials. A scheme is presented herein to provide operational uniformity in conjunction with exits on the Interstate System of highways.

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INTRODUCTION

A novel interchange to handle traffic at the intersection of two highways was introduced in 1928. This first cloverleaf, at Woodbridge, New Jersey, permitted all traffic, including left-turning movements, to operate through the intersection without interruption. Since then, engineers have come a long way in the development of design techniques to handle conflicting traffic movements. Many expressways and freeways, incorporating elaborate interchanges, have been built, mostly in and near urban areas. In recent years a new art has sprung up: interchange design, combining the talents of the highway engineer (geometric) and the traffic engineer. This experience has brought about advances in design techniques which are being put to use effectively in the development of the vast network of Interstate highways. The profession, however, is still faced with new traffic operation problems and is developing new design concepts for these interregional freeways.

The utility of this important system of highways will be influenced by the

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Note: Discussion open until June 1, 1958. A postponement of this closing date can be obtained by writing to the ASCE Manager of Technical Publications. Paper 1525 is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. HW 1, January, 1958.

- a. Paper prepared for presentation at meeting of the American Society of Civil Engineers, New York, N. Y., October, 1957.
1. Chief Highway Engr., De Leuw, Cather & Co., Chicago, Ill.

location and design of interchanges—interchanges which will provide access to and from literally thousands of intersecting highways, as well as those which will interconnect various parts of the system. Selecting the proper type of interchange for each of these locations is the first and perhaps the most important step in design.

In urban areas the problem is primarily that of providing adequate capacity and efficient operation. Where possible, the design should be sufficiently flexible to permit future adjustment and expansion. In rural areas the problem is generally that of adopting interchange arrangements in keeping with the character of the intersecting highway. More important, the layout must be compatible with traffic operation at high sustained speeds of the order experienced on turnpike facilities.

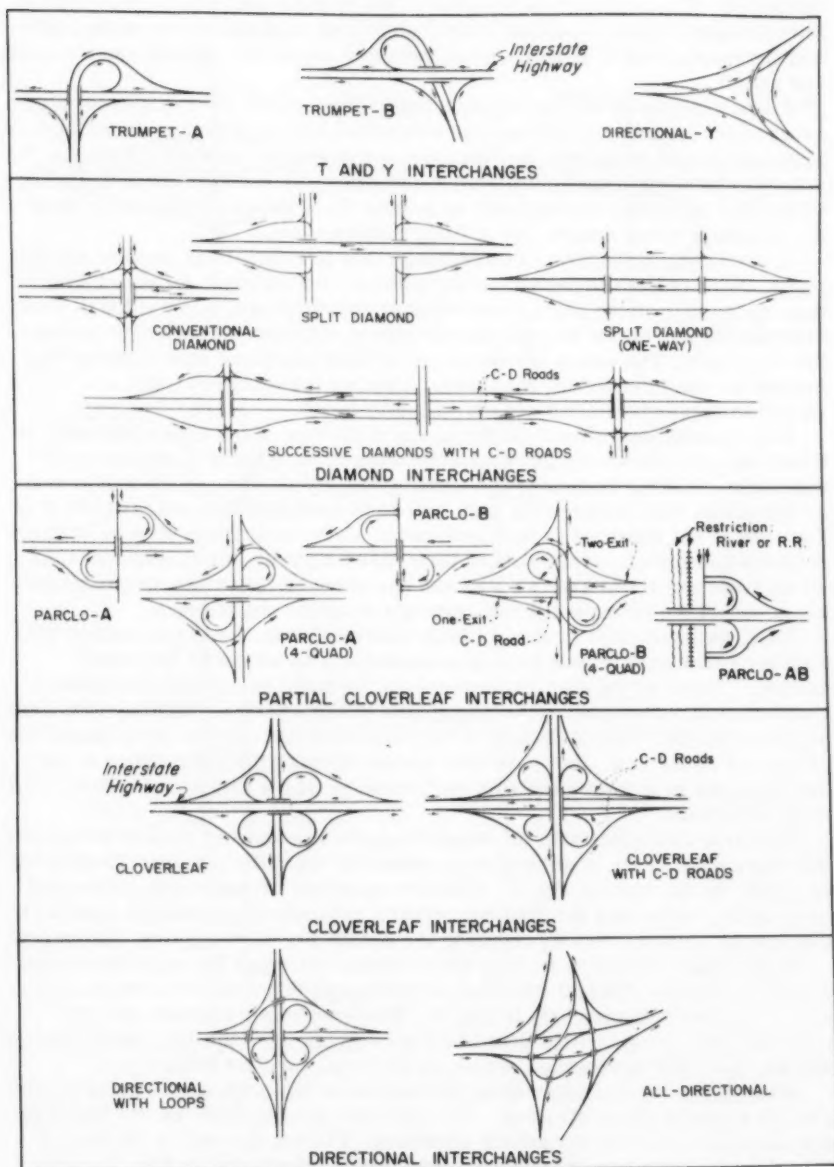
This paper discusses the types of interchanges adaptable to various conditions found on the Interstate system of highways. The approach taken is different in that the type and character of the intersecting street or highway is considered first and then the forms of interchanges fitting to it are discussed; rather than taking each type of interchange and showing under what variety of conditions it may be used. In this regard the adaptability of interchange types is discussed with respect to minor crossroads (rural), major streets (urban), primary highways (rural and suburban), and expressways and freeways. In urban areas the capacity potentials of the cloverleaf, partial cloverleaf, and diamond interchanges are developed and compared. In rural areas the characteristics of interchanges and their suitability are presented primarily with regard to safety and operational features. The need for and the means of effecting uniformity in operational patterns of ramp exits through the use of collector-distributor roads are thoroughly discussed in the light of high standards and maximum safety indicated for this important system of highways.

General forms of interchanges and terminology therewith are shown in Fig. 1. T and Y interchanges are not discussed specifically since generally they have the operational characteristics of directional interchanges, referred to below. Several abbreviations and new terms are introduced for easy reference.

For instance, a distinction is made between the two variations of trumpets: the one with the loop in advance of the intercepted road (with respect to direction of travel) is referred to as the trumpet-A, the letter A used to denote the loop in Advance; and the one with the loop beyond the intercepted road as the trumpet-B. The same principle is applied to the partial cloverleafs, for which a new abbreviation, the parclo, is introduced. Considering the direction of travel on expressway as a base, the interchange with the loops in advance of the crossroad is referred to as parclo-A, and the one with the loops beyond the crossroad as parclo-B. Those with additional right-turn ramps in the other two quadrants are referred to as parclo-A (4-quad) and parclo-B (4-quad), respectively. Collector-distributor roads, which now are receiving considerable attention either as parts of individual interchanges or facilities between successive interchanges, are abbreviated herein as C-D roads.

#### Interchanges with Minor Crossroads (Rural)

Because Interstate highways constitute a free system, interchanges on it are called for at some locations where the crossroad is minor or of local



INTERSTATE HIGHWAYS  
INTERCHANGES - GENERAL TYPES AND TERMINOLOGY

FIGURE 1

character. This situation is common in the western and mid-western states. Interchanges at such locations avoid unduly long sections of Interstate highway between points of egress and ingress and makes the system more flexible and useful.

Little experience has been gained with operation of interchanges at minor crossroads because, in the past, no controlled access highways of any appreciable length have been built in sparsely settled or undeveloped areas. Because the volume of traffic on such roads generally receives little or no consideration in design, the tendency is to take the problem lightly and to treat the design as being simple and of little consequence.

In such cases, the form of interchange that first comes to mind is the diamond. With respect to the Interstate highway, the layout is ideal in that one high-speed exit on the right, in advance of the structure, is provided in each direction of travel, as well as one high-speed entrance on each side beyond the structure. The entire layout occupies little additional space beyond that needed for the intersecting highways. Also, on the crossroad, the arrangement appears simple and direct. But, is it?

In examining operational features, the character of the crossroad must be taken into consideration. Here is a two-lane road which will remain so indefinitely. In some instances the existing facility is a 16- or 18-foot gravel or macadam road, or possibly a 20-foot hard-surfaced road. Traffic on it is light and is not expected to increase much. Drivers are accustomed at intersections along such rural roads to turn either right or left as desired; i.e., all intersecting roads are two-way and any one-way operation, or prohibited turns, would not be expected and certainly would be out of place.

Thus, as illustrated in Fig. 2, the diamond interchange in conjunction with a minor rural road invites improper maneuvers as shown by the heavy arrows. These wrong-way movements can be made easily and can produce, inadvertently, travelling on the wrong side of the Interstate highway with very serious results. Channelization of the ramp terminals helps little, unless the crossroad is divided. But, a divided section through the interchange is not justified, nor is it in keeping with the character of the crossroad. Then, what is the solution?

A partial cloverleaf with the loops along the expressway located beyond the structure (parclo-B), may be used to eliminate the difficulty described above, as shown on the right of Fig. 2. This two-quadrant arrangement, although a little more costly than the diamond, greatly minimizes operational hazards by eliminating or considerably reducing the possibility of wrong-way movements.

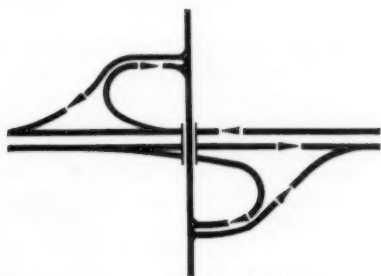
In this plan, all traffic leaving the crossroad to reach the expressway operates in a manner identical with that on the diamond, as may be seen in comparing the two arrangements in Fig. 2. The two ramp terminals are conventional two-way junctions with which all drivers are familiar, regardless of whether the road is minor or major, or the area rural or urban.

With respect to traffic entering the Interstate highway, the connections are similar to those of the diamond. The exits are similar also, except that they are normally provided beyond the structure. Placing the exit in advance of the structure, however, can be accomplished as illustrated in Fig. 2 in conjunction with the loop ramp in the lower-right quadrant.

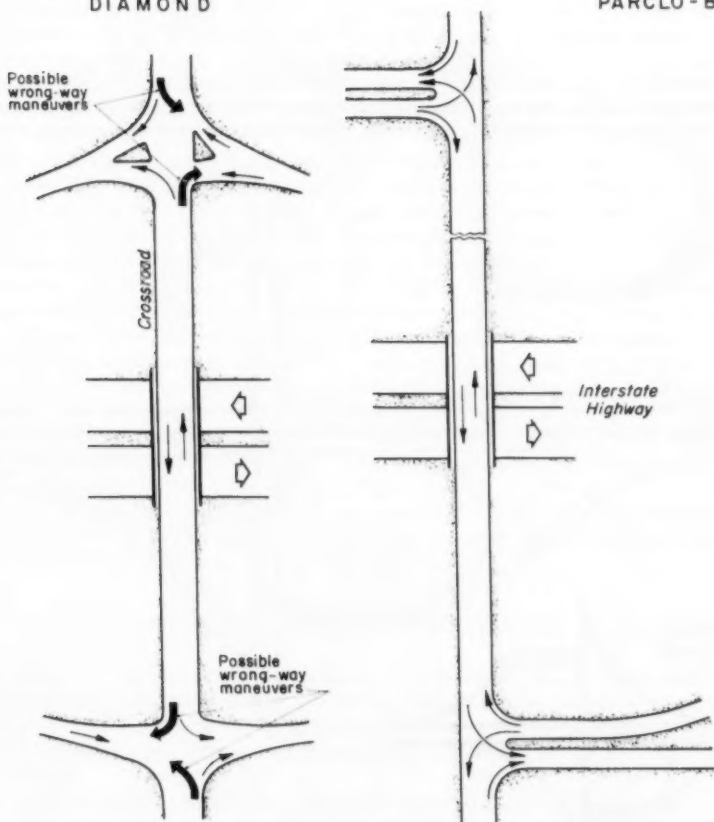
Since the parclo-B is a suitable arrangement at minor crossroads, the question naturally arises as to whether the other form of partial cloverleaf, the parclo-A, is also appropriate. The two-quadrant arrangement, as illustrated in the upper part of Fig. 3, like the parclo-B (Fig. 2) eliminates or



DIAMOND

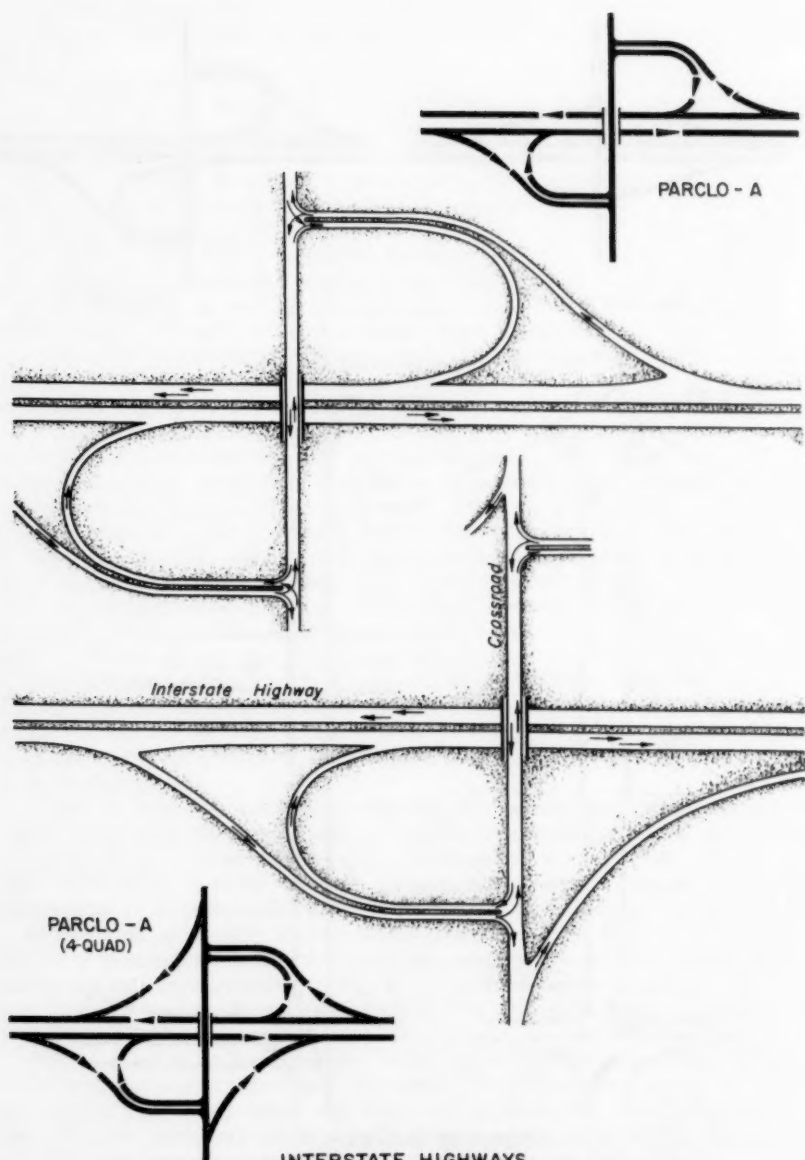


PARCLO - B



INTERSTATE HIGHWAYS  
ADAPTABILITY OF PARCLO - B INTERCHANGE  
TO MINOR CROSSROADS—RURAL  
AND ITS COMPARISON WITH DIAMOND INTERCHANGE

FIGURE 2



INTERSTATE HIGHWAYS  
OPERATIONAL FEATURES OF PARCLO-A INTERCHANGES  
AND THEIR SUITABILITY AT MINOR CROSSROADS

FIGURE 3

considerably reduces the possibility of wrong-way movements. Its drawback, however, is that right-turn movements are unnatural, requiring direct left turns at the crossroad.

This objection is overcome in the plan below where the parclo-A is expanded to four quadrants. In this form, no exits on the crossroad are made via left-turn maneuvers. This feature precludes left turning vehicles from standing on the travelled way waiting for an opportunity to turn; i.e., it minimizes the hazard of rear-end collisions where speeds are high or, where traffic volumes are of concern, it appreciably increases capacity. Note also that the two added ramps, upper-left and lower-right quadrants, are not at all inviting to wrong-way movements. But, for the type of crossroad considered here, this variation of the parclo-A is apparently too elaborate and costly.

Another form of interchange not illustrated in detail but shown diagrammatically as the parclo-AB in Fig. 1, may be employed in special cases where the crossroad closely parallels a river or a railroad. Crossroad realignment to permit the use of parclo-B interchange generally would be preferred for operational reasons.

As summarized in Fig. 4, the parclo-B obviously is the most suitable form of interchange where the Interstate highway crosses a minor (rural) road. It provides conventional and simple operation through two at-grade ramp terminals, compatible with the character of the minor crossroad. The same form of interchange but with right-turning ramps added in the other two quadrants, however, is considered inappropriate, because these ramps invite wrong-way movements and the layout is too elaborate for the condition.

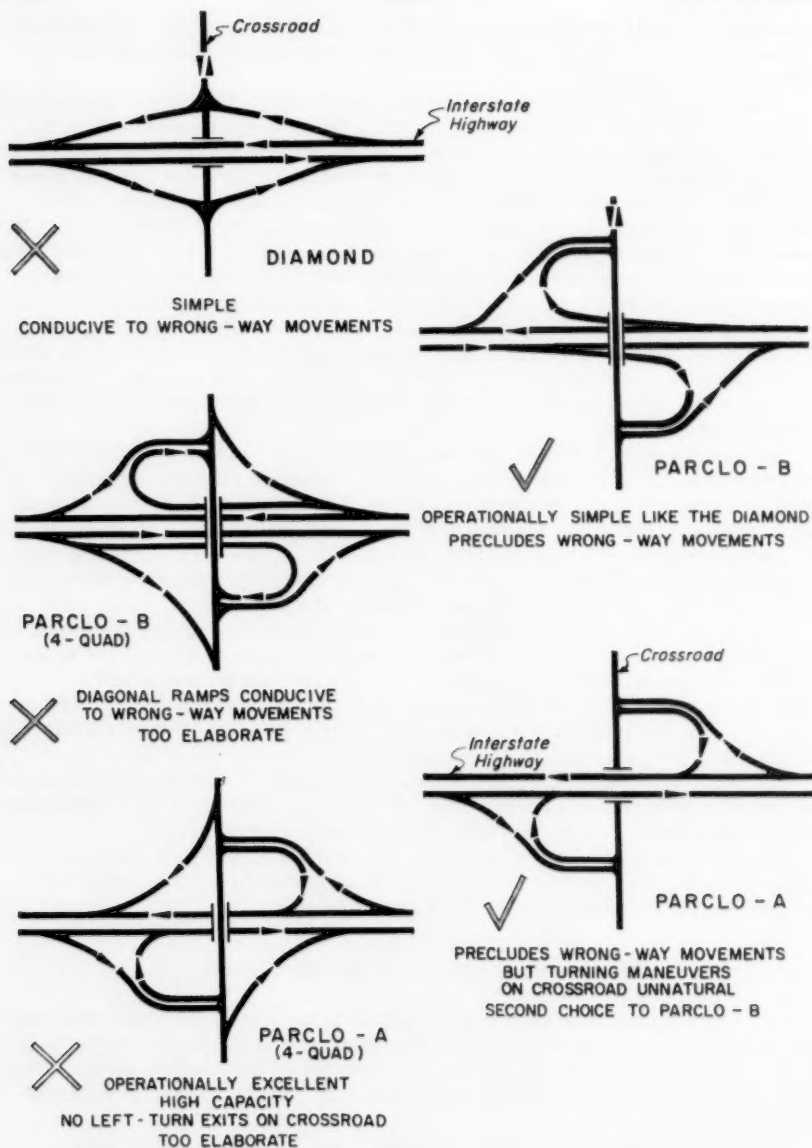
Parclo-A, which also incorporates the design feature at ramp terminals to eliminate wrong-way operation, involves unnatural turning maneuvers by requiring direct left turns to take place on the crossroad for movements destined to the right on the expressway. Although less desirable, it may be used in place of parclo-B where physical features or right-of-way restrictions do not allow the development of a parclo-B interchange. A parclo-A interchange with two additional right-turning ramps in the quadrants otherwise unoccupied is an excellent arrangement for a major street or in some cases for a primary highway, but is over-designed for a minor crossroad.

The diamond, although it is simple in pattern and requires little right-of-way, obviously is an inappropriate interchange at minor (rural) crossroads because it is so conducive to wrong-way movements.

#### Interchanges with Major Streets (Urban)

Two basic forms of interchanges fitting at crossings of Interstate highways and major streets in urban areas are the diamond and the partial cloverleaf. A full cloverleaf generally is not suitable because of the large space it occupies, and because the continuous movements provided by it are not required on the street.

The simplest and perhaps the most used form of interchange at intersections of major streets is the diamond. The objection to it—the open invitation to wrong-way movements, as indicated above in conjunction with minor crossroads in rural areas—does not apply in built-up districts. Here, the use of one-way streets and the prohibition of turns are expected and accepted so that the one-way ramp terminals are in keeping with normal operation. In fact, the ramps usually are connected to continuous frontage roads which are



INTERSTATE HIGHWAYS  
INTERCHANGES ADAPTABLE TO MINOR CROSSROADS-RURAL

one-way. Moreover, the rebuilt portion of the street through the interchange generally is divided and the ramp terminals channelized, making intended operation more obvious.

Three variations of the diamond, Fig. 5, may be employed—conventional diamond, split diamond, and split diamond with one-way cross streets. The suitability of each depends upon traffic requirements, right-of-way availability, and the pattern of adjoining streets. The efficiency and capacity of the diamond are increased when it is split, and further increased when the cross streets are made one-way.

This is shown by an example in Fig. 6, indicating conditions representative of any large metropolitan area. The traffic indicated is in conjunction with two major streets at which an interchange is to be provided. The existing streets are each four lanes wide, one or both of which are to be utilized for the interchange. With this basic information, the solutions using the three forms of diamond interchanges are demonstrated in Figs. 7 to 9.

The conventional diamond, as shown in Fig. 7, requires the widening of one street to seven lanes through the interchange or 88 feet between curbs. The other street remains four lanes wide; thus, a total of eleven lanes is used. One of the left-turn movements from the widened cross street has to be accommodated on two lanes. Three-phase control is called for here, utilizing a long cycle in the order of 80 seconds. Because of this, signal waiting time is increased.

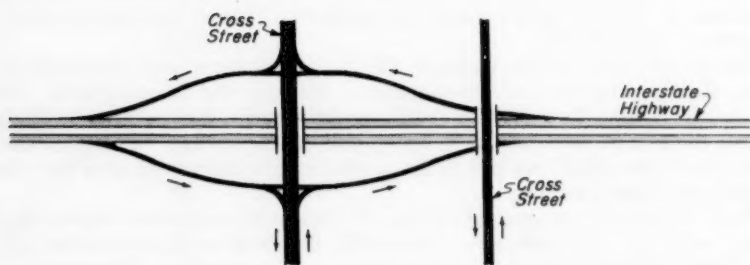
In using the split diamond, Fig. 8, the existing cross streets are each widened by one lane, resulting in curb-to-curb widths of 64 feet. Here a total of ten lanes is utilized, as compared with eleven lanes in the previous example. Although only one less lane is used as a total, each street is not unduly wide. The number of traffic conflicts have been reduced and the operational efficiency considerably increased by the use of a two-phase, approximately 60-second cycle instead of the longer, three-phase signal.

The split diamond with one-way operation, Fig. 9, requires no increase in the number of lanes on the two existing streets. Here, a total of eight lanes is used, as compared with 11 and 10 lanes in the other two cases. With all one-way operation and two-phase, 60-second cycle signal, high operational efficiency is realized, resulting in higher capacity and higher overall speeds, made possible by the use of an effective progressive signal system.

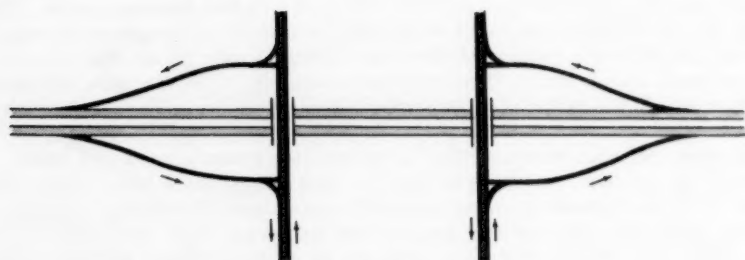
Where a conventional diamond does not have sufficient capacity and a split diamond is not feasible, a parclo-A (4-quad) interchange may be employed. For heavy traffic conditions, particularly large, left-exit movements on the cross street, this form of interchange is very appropriate, providing a high degree of operational efficiency and a potential to handle unusually large traffic volumes.

The example in Fig. 10, using rather high but realistic turning volumes, is designed to show the effectiveness of the parclo-A. To handle the indicated traffic, a conventional diamond, as shown in the left part of the figure, requires a total of 10 lanes, or a curb-to-curb width of 124 feet. Such design, involving a widening in each direction from a normal width of three lanes on the approaches to five lanes through the interchange including a double left-turn lane, is awkward and inefficient, and normally would not be considered a practicable design.

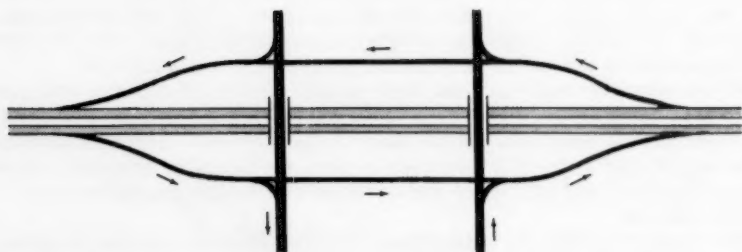
A parclo-A (4-quad) interchange, shown in the center part of Fig. 10, handles the same traffic volumes effectively on a six-lane street, 76 feet between curbs. In this case, the normal width of street on the approaches is



CONVENTIONAL DIAMOND



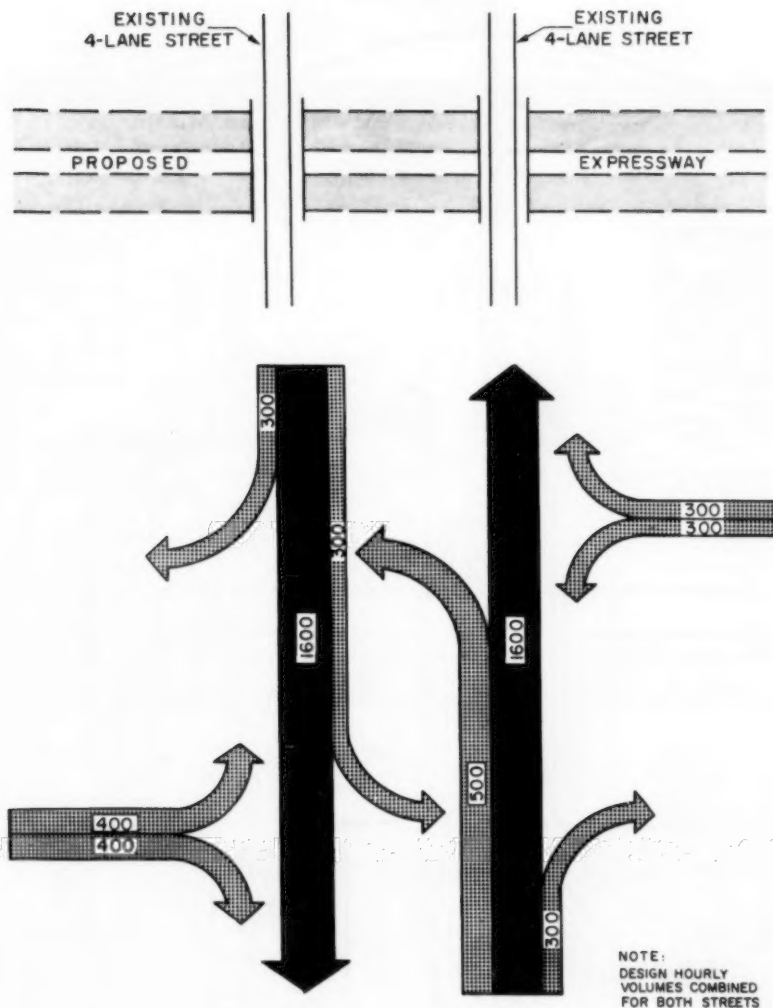
SPLIT DIAMOND



SPLIT DIAMOND WITH ONE - WAY CROSS STREETS

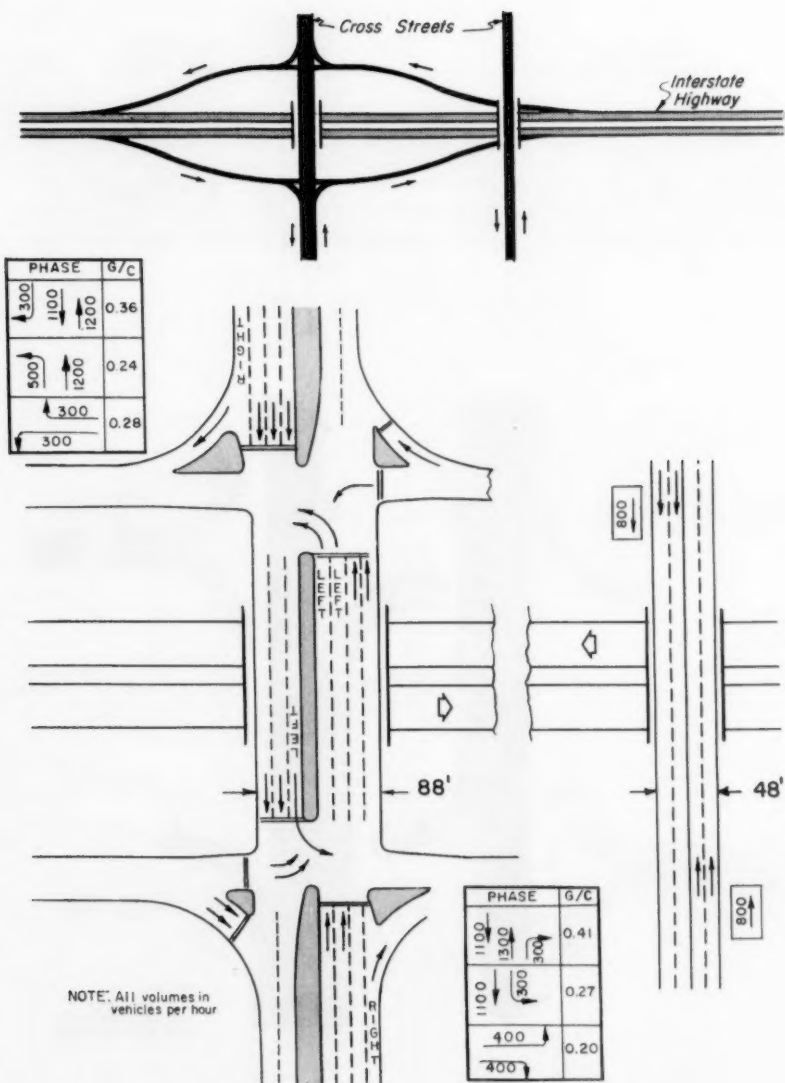
INTERSTATE HIGHWAYS  
VARIATIONS OF DIAMOND - TYPE INTERCHANGES

FIGURE 5



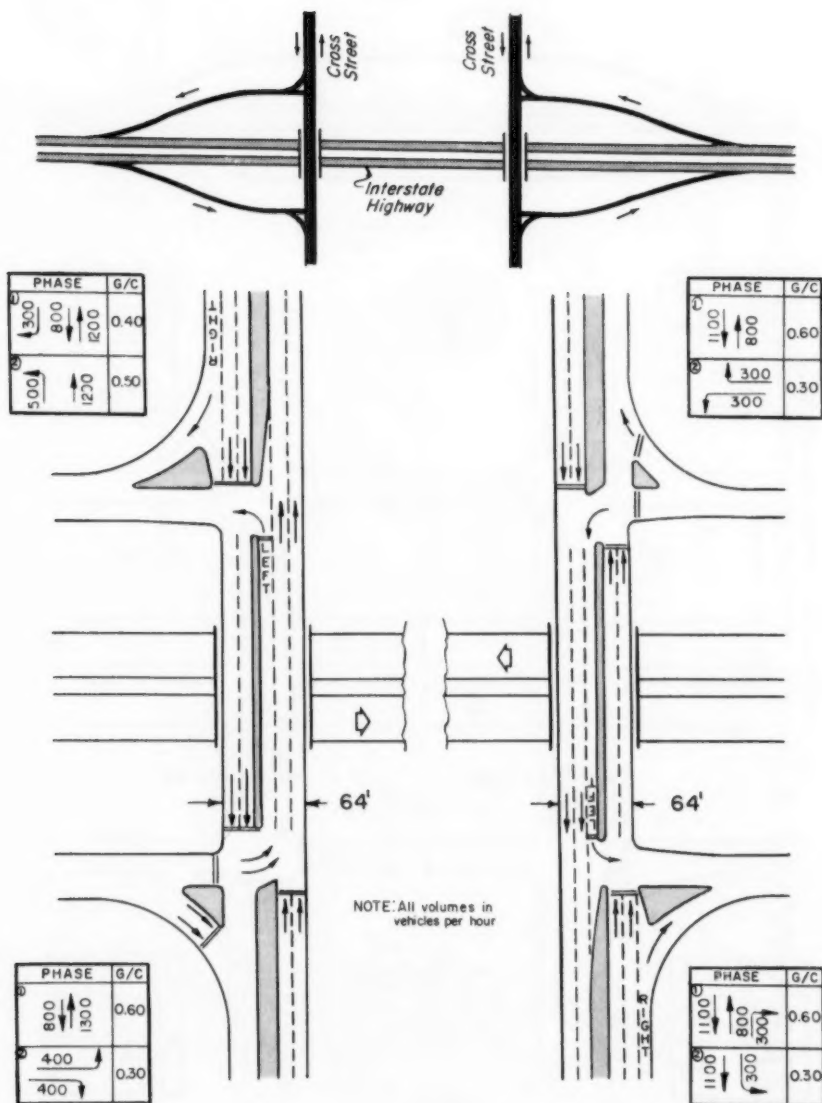
INTERSTATE HIGHWAYS  
ILLUSTRATIVE PROBLEM FOR DIAMOND INTERCHANGES  
CONDITIONS FOR SOLUTIONS IN FIGURES 7 TO 9

FIGURE 6



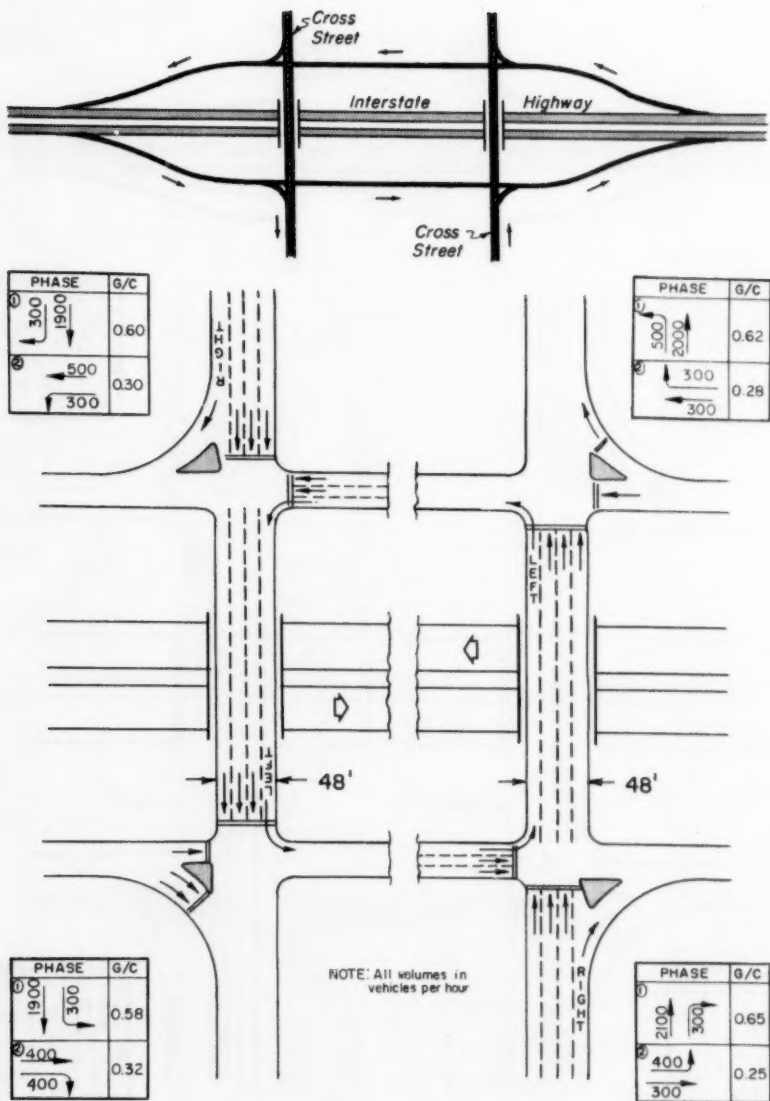
# INTERSTATE HIGHWAYS ILLUSTRATIVE PROBLEM—CONVENTIONAL DIAMOND

FIGURE 7



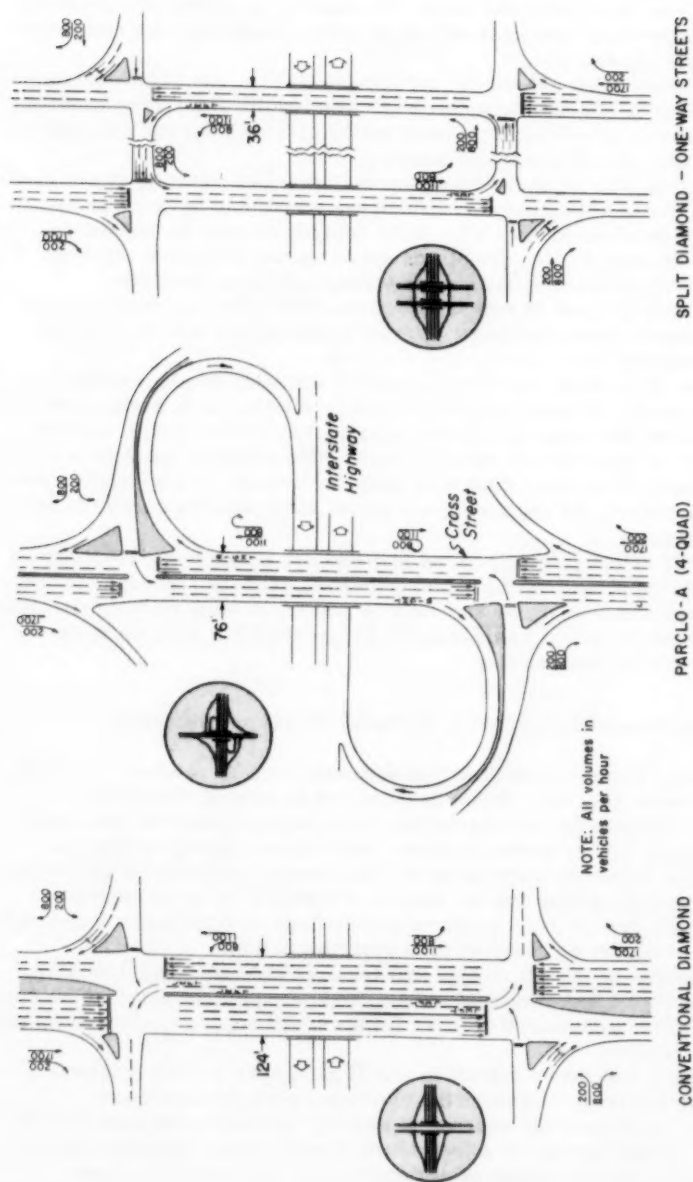
INTERSTATE HIGHWAYS  
ILLUSTRATIVE PROBLEM—SPLIT DIAMOND

FIGURE 8



INTERSTATE HIGHWAYS  
ILLUSTRATIVE PROBLEM—SPLIT DIAMOND  
WITH ONE-WAY CROSS STREETS

FIGURE 9



ADAPTABILITY OF PARCLO A (4-QUAD) INTERCHANGES TO MAJOR STREETS  
AND ITS COMPARISON WITH DIAMOND INTERCHANGES

FIGURE 10

continued through the interchange. It utilizes normal two-phase signal control. Moreover, with additional width, the capacity can be further increased. In fact, the capacity of this interchange, for some conditions, is greater than that of the full cloverleaf.

The right part of Fig. 10 shows that this traffic also can be handled on a split diamond with one-way cross streets. The results are almost identical with the parclo-A, producing equivalent widths of travelled ways and approximately the same signal timing and capacity.

Summarizing, Fig. 11 shows three forms of diamond interchanges—conventional, split and split (one-way)—which are suitable in conjunction with major streets in urban areas. The choice depends on specific conditions. Splitting the diamond greatly simplifies operation and increases capacity. One-way operation on the cross streets further improves efficiency.

The parclo-A (4-quad) is just as effective as the split (one-way) diamond and is used where the conventional diamond is inadequate and the split diamond inappropriate.

The parclo-B (4-quad) also may be used to advantage in place of the conventional diamond. Although not as efficient as the parclo-A, because the two direct left-turns are made off rather than onto the cross street, it may be employed where right-of-way restrictions or other physical controls preclude the development of the more desirable interchange type. It also utilizes two-phase signal control, but requires more street width than the parclo-A due to left-turn lanes.

The full cloverleaf generally is not justified nor fitting to the environment of a major street in built-up districts. However, primary highways carried into or through cities as major streets may justify, in some parts of the urban area, the use of cloverleaf interchanges. Characteristics of cloverleaves are discussed under the next heading.

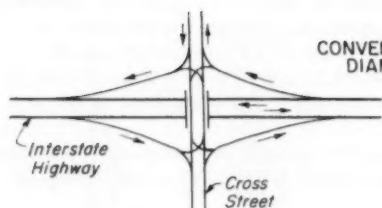
#### Interchanges with Primary Highways (Rural and Suburban)

Interchanges between Interstate highways and primary roads in rural and in suburban areas generally should be patterned to provide continuous movements. Accordingly, an appropriate form of interchange in such cases is the cloverleaf. Other forms, however, which do not provide continuous operation, may be fitting under some circumstances, depending on the character of the primary highway and the amount of traffic to be accommodated. These primarily are the four-quadrant, parclo-type interchanges. In special cases, a diamond may be resorted to in suburban areas.

The discussion relative to operational features and capacity potential of the various diamond and parclo interchanges given under the previous heading applies here also. Discussion of these features with regard to cloverleaves is presented as follows.

A basic feature of the cloverleaf is that it must have divided roadways through the interchange. Although the cloverleaf provides continuous movements, it does so at the expense of weaving maneuvers between the left-turning movements handled on adjacent loop ramps. This characteristic of the cloverleaf is not considered objectionable even for relatively heavy volumes on the primary highway. It is undesirable, however, on an Interstate highway unless design speed is low and traffic is light.

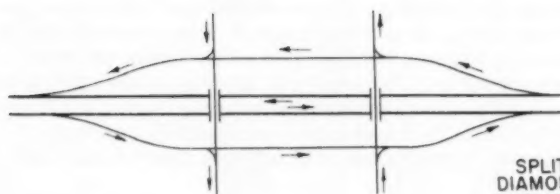
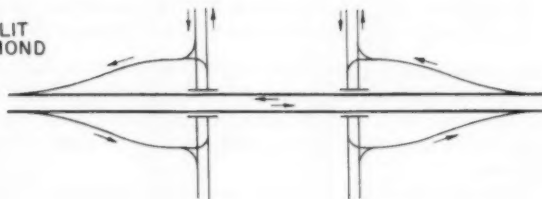
Any interchange design should be tested for capacity in selection of type,

CONVENTIONAL  
DIAMOND

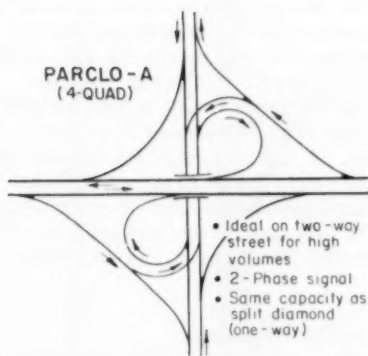
- Suitable for low to moderate volumes
- 3-Phase signal

SPLIT  
DIAMOND

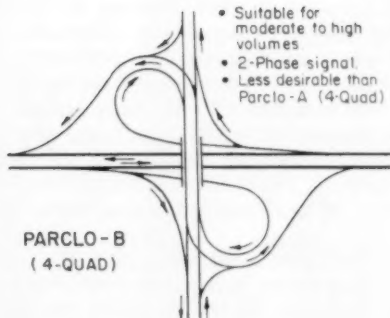
- Suitable for moderate to high volumes
- 2-Phase signal

SPLIT  
DIAMOND  
(ONE-WAY)

- Suitable for high volumes
- 2-Phase signal
- Highly efficient

PARCLO-A  
(4-QUAD)

- Ideal on two-way street for high volumes
- 2-Phase signal
- Same capacity as split diamond (one-way)

PARCLO-B  
(4-QUAD)

- Suitable for moderate to high volumes
- 2-Phase signal
- Less desirable than Parclo-A (4-Quad)

INTERSTATE HIGHWAYS  
INTERCHANGES ADAPTABLE TO MAJOR STREETS - URBAN

FIGURE II

and again in establishing the details of design to assure a proper and adequate arrangement. But before this is done, it would be well for the designer to have some concept of what the capacity potential of the cloverleaf may be under various traffic patterns and volume conditions. This is diagrammed in Figs. 12 and 13 for both rural and urban conditions, including variations with collector-distributor roads.<sup>2</sup>

Three traffic patterns are used to illustrate a complete range of conditions of traffic loading, each producing design or practical capacity conditions, as follows:

- 1) Highest equal volumes occurring simultaneously on adjacent loops;
- 2) Highest volume occurring on the exit loop; and
- 3) Highest volume occurring on the entrance loop.

Also, as a control, the first exit of the interchange involving the right turn movement is taken as a range from zero to a volume equivalent to design capacity of the exit. Predicated on these conditions, the travelled way of approach and exit ends of the interchange are then loaded to or near practical capacity.

With the above as a basis, the traffic carrying ability of the cloverleaf over a whole range of conditions is revealed. Also, direct comparison for each case is made between a conventional cloverleaf and one with C-D roads.

For rural conditions the capacity of a conventional cloverleaf, left half of Fig. 12, is limited generally to a weaving volume of 1000 vph<sup>3</sup> and a lane capacity base of 900 vph, considering 10 percent trucks.<sup>4</sup> A six-lane facility is assumed, so that the design or practical capacity on either end of the interchange is 2700 vph in each direction. The practical capacity of the exit ramp is taken as 700 vph. For each of the three cases of weaving traffic, there are two limits of turning traffic which the interchange is capable of handling; these are shown by two sets of traffic values, one set with and the other without parentheses.

On the right half of Fig. 12 is shown the traffic that can be handled by a cloverleaf with C-D roads for the same three cases of weaving patterns and two limits of turning traffic. Capacity of the through traffic lanes is the same as above, 900 vph per lane or 2700 vph in each direction on the approaches. The design speed is lower on the C-D road than on the expressway proper and the weaving is completely removed from other traffic on the expressway. Greater weaving volumes, therefore, can be handled; namely, a total of 1200 to 1350 vph for a two-lane, and up to 1500 vph for a three-lane C-D road.<sup>5</sup>

By comparing horizontally across in Fig. 12, the additional traffic that can be handled by the latter arrangement can be seen. Items of comparison include (1) weaving capacity, (2) maximum turning volumes, and (3) expressway capacity. Differences are not great, but the increase in weaving capacity of from 20 to 35 percent is considered significant. But of greater importance

2. Hereafter referred to as C-D roads.

3. Sum of two movements—entering plus exiting volumes.

4. Based on Highway Capacity Manual—1950, p. 115, and AASHO Policy on Geometric Design of Rural Highways, p. 101, assuming a representative length of weaving section of about 500 feet.

5. Based on lane capacity of 1200 vph; see AASHO Policy on Arterial Highways in Urban Areas—Fig. J-7 and discussion under heading of Weaving Sections, p. 490.

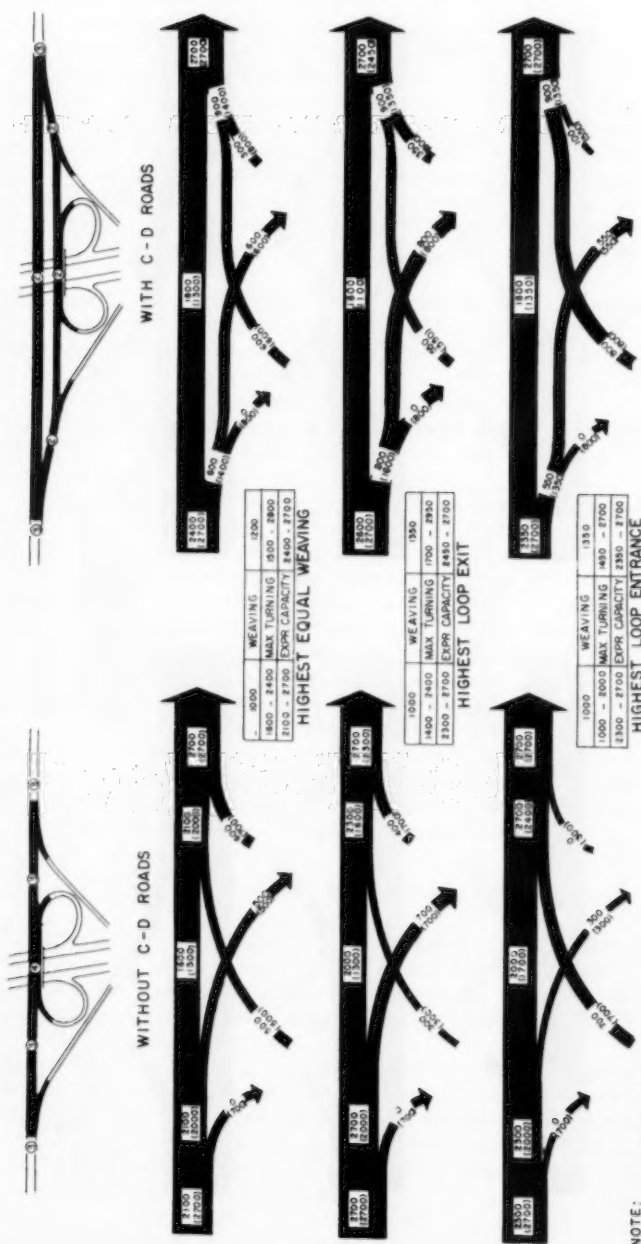
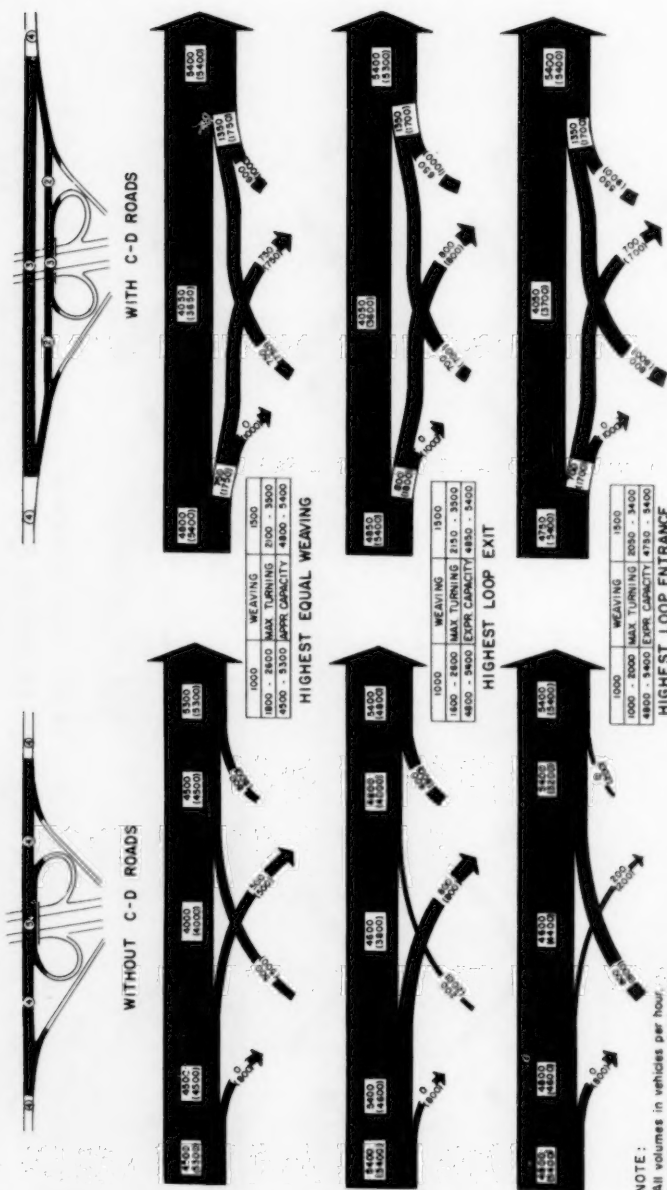


FIGURE 12



CAPACITY POTENTIAL OF CLOVERLEAF INTERCHANGES - URBAN  
INTERSTATE HIGHWAYS

FIGURE 13

are the safety and operational advantages offered by the design with C-D roads. This is further discussed under another heading.

The same type of analysis also has been applied to an urban condition as illustrated in Fig. 13. In this case the design or practical capacity on the approaches, considering 10 percent trucks, is 1350 vph per lane, or 5400 vph on a four-lane approach. Design capacity of a single-lane ramp leaving the highway is taken at 800 vph and one leaving the C-D road at 1000 vph.

For the conventional cloverleaf in urban areas, the capacity is limited to a weaving volume of 1000 vph, with 1200 vph per lane as the design capacity base for the weaving section.<sup>6</sup> The amount of traffic that can be handled by an ordinary cloverleaf under various conditions is shown on the left half of the figure.

The capacity of a cloverleaf in urban areas can be considerably increased by the use of C-D roads as shown in the right half of the figure. Weaving volumes up to 1500 vph can be accommodated, with 1200 vph per lane as the design capacity base.<sup>6</sup> Comparing the two arrangements, the plan with C-D roads can handle 50 percent more weaving traffic. As to total interchanging traffic, greater volumes also can be accommodated—17 to 35 percent more in the first case, 35 percent more in the second case, and 70 to 100 percent more in the third case.

Interchanges adaptable to primary highways, Fig. 14, are summarized as follows:

In rural areas the cloverleaf generally should be considered as most acceptable. A parclo-A (4-quad) on the less important primary highways may also be suitable. On the high-speed, relatively high-volume primary highways, directional types of interchanges may be appropriate. All other forms, which require troublesome or hazardous maneuvers created by direct left turns on the highway, generally should be avoided.

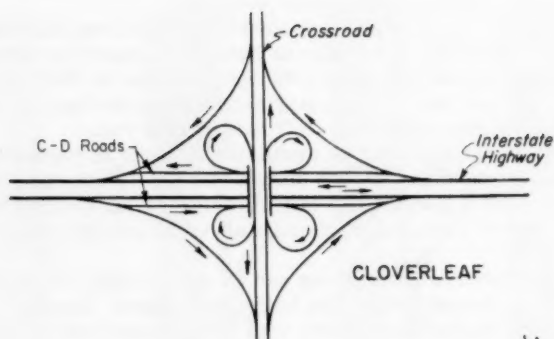
In suburban areas the cloverleaf also is a desirable type, but where speeds are nominal and occasional at-grade intersections are present on the highway, a parclo-A (4-quad) interchange usually is appropriate. Although less desirable, a parclo-B (4-quad) may be employed where it is not feasible to develop a parclo-A interchange. As a last resort, a diamond interchange may be considered but the crossroad should be properly divided.

#### Interchanges with Expressways and Freeways

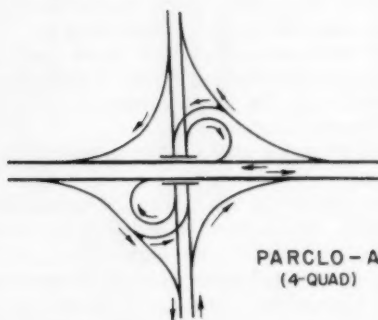
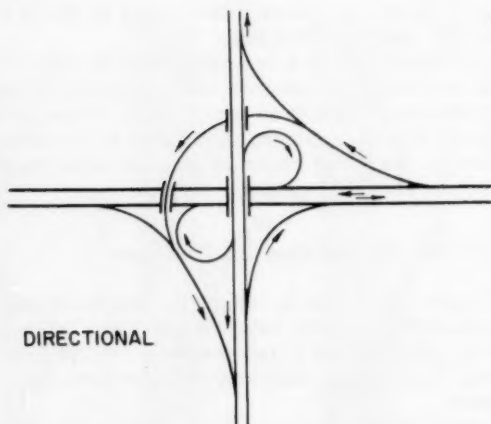
Directional type interchanges are called for where the Interstate highway intersects or joins an expressway or another Interstate highway. Cloverleafs normally are not adaptable at interchanges of two freeways, except possibly in rural areas where turning volumes are relatively low; and then, only where the design includes C-D roads.

There are numerous types of directional interchanges which may be employed on Interstate highways. Most of the basic forms are diagrammed in the AASHO Policy on Arterial Highways in Urban Areas. The suitability of any one at a particular location depends primarily on the pattern and volumes of traffic and on site controls. Directional interchanges may be typed several ways, as depicted graphically in Fig. 15:

6. AASHO Policy on Arterial Highways in Urban Areas—Fig. J-7 and discussion under heading of Weaving Sections, p. 490.



CLOVERLEAF

PARCLO - A  
(4-QUAD)

DIRECTIONAL

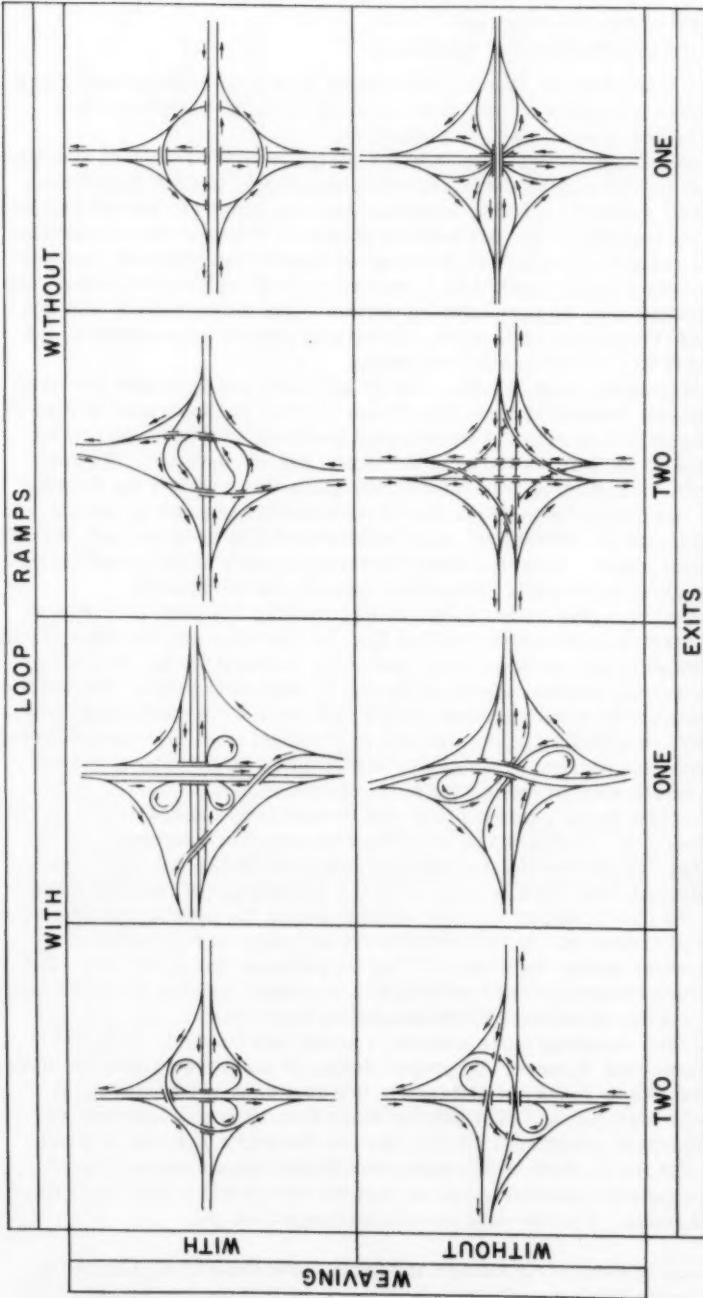
**NOTE:**

In Suburban areas:

- Parclo - B (4-Quad) may be used in lieu of Parclo - A (4-Quad); not as desirable.
- Diamond may be used in special cases; otherwise avoided.

**INTERSTATE HIGHWAYS  
INTERCHANGES ADAPTABLE TO PRIMARY HIGHWAYS - RURAL**

FIGURE 14



INTERSTATE HIGHWAYS  
CLASSIFICATION OF DIRECTIONAL INTERCHANGES  
WITH RESPECT TO THREE BASIC OPERATIONAL CHARACTERISTICS  
FIGURE 15

- a) With or without loops (latter referred to as all-directional);
- b) With or without weaving; and
- c) With one or two exits per approach.

The first consideration, whether the design is with or without loop ramps, is usually not too important, provided the major turning movements are handled on direct or semi-direct connections.

The second characteristic, whether the design is with or without weaving (either along one or both of the intersecting highways), is most significant. Every attempt should be made to eliminate weaving along the Interstate highway. It is recommended that all weaving should be removed from Interstate highways in rural areas where high sustained speeds are attained; moreover, no major weaving section should be tolerated on such highways in urban areas. Weaving sections may be precluded by certain ramp arrangements and additional grade separation structures, or weaving may be removed from the main line of traffic by the use of C-D roads.

The third consideration, whether one or two exits per approach are used, is an operational feature of some significance. This is illustrated in Fig. 16.

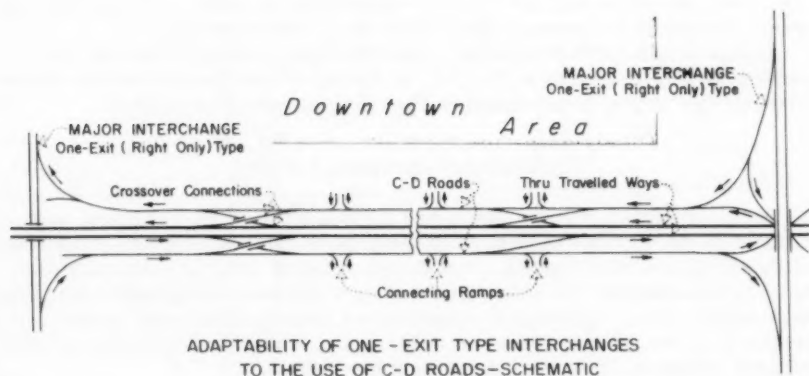
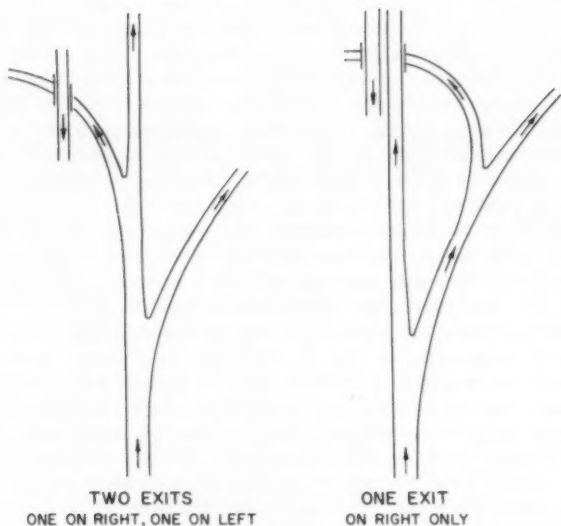
An approach to a directional interchange involving two exits, one on the right and one on the left, is shown at the upper left of the figure. Its basic characteristic is that an approaching driver preparing to leave the freeway must make two decisions: (1) that the interchange ahead is or is not the one he is seeking; and (2) whether he must bear to the right or to the left, depending on his destination. Here the latter decision is made while travelling on the freeway along with traffic proceeding through the interchange.

An approach to a directional interchange involving one exit, on the right only, is illustrated at the upper right of Fig. 16. In this case, the approaching driver makes only one decision while travelling on the freeway, whether or not the intersecting highway ahead is the one he wishes to enter. The second decision, whether he should proceed to the right or left, is made while travelling at a reduced speed along the exit ramp, removed from high-speed through traffic. Here, too, signing is simplified and is more direct than in the two-exit arrangement, thus providing for safer operation.<sup>7</sup>

In the two-exit design, drivers bear left to turn left, and bear right to turn right. This may be considered an advantage because such maneuvers are natural. They are natural on at-grade intersections where the driver sees and turns directly onto the crossroad, but not on high-speed, expansive lay-outs where the driver begins his turn without seeing the crossroad, sometimes a quarter-mile removed. Moreover, drivers normally are accustomed to leave the freeway on the right and may not be prepared for a left exit. The two-exit arrangements also are subject to more lane-changing in maneuvering for proper position in advance of the exits than in the case of one-exit arrangements, thus creating more internal weaving and friction. This can be alleviated somewhat, however, by proper design of maneuver areas and spacing of the two exits. Required distance is 600 feet or more according to AASHO design criteria, and 1000 feet or more according to California Division of Highways' standards. Such distances often are difficult to obtain.

Another feature of the one-exit type interchange, which makes it most adaptable within metropolitan areas, is that the design fits a pattern of continuous C-D roads. The two-exit type interchange does not.

7. Correlation of Geometric Design and Directional Signing, by George M. Webb, Traffic Engineer, California Division of Highways—October, 1956.



INTERSTATE HIGHWAYS  
CHARACTERISTICS OF ONE-EXIT AND TWO-EXIT TYPE  
DIRECTIONAL INTERCHANGES

FIGURE 16

Freeways in large cities located adjacent to or near the central business district, particularly those forming part of an inner loop or circumferential highway, invariably call for more lanes than can be reasonably used to accommodate future (1980) traffic on a single facility. Anticipated ADT volumes in the range of 100 to 150 thousand vehicles in these areas are common. Unwieldy widths of pavements and unworkable weaving sections would often be required to handle such traffic at practical or design capacity (with a normal rather than an extended peak period condition) and still provide the frequency of exits and entrances demanded by traffic. In other words, such large traffic loads cannot be handled properly on a normal freeway.

The problem can be solved, however, on a single facility, if the troublesome weaving maneuvers are removed from the main line of travel. This is done by providing C-D roads continuously for a mile or more between major interchanges, as depicted in the lower part of Fig. 16. Such arrangements cannot be effected however, without the use of one-exit type interchanges.

As shown schematically in Fig. 16, the inner or freeway lanes are free of the disturbance and weaving created by leaving and entering traffic. The inner lanes have the characteristics of express lanes and thus develop high speeds and high capacities, retaining the intended qualities of freeway operation. Such arrangements, it is believed, will become commonplace, permitting on some sections of the circumferential the use of a total of 12 to 16 lanes on four travelled ways. The only other solution is the provision of parallel but independent freeways, which may be more difficult of attainment in built-up areas.

In many instances the C-D roads need not be constructed at once, but may be future adaptations if the principal interchanges are designed to be one-exit types and sufficient right-of-way—sometimes no additional right-of-way where the taking is already a block wide—is provided initially.

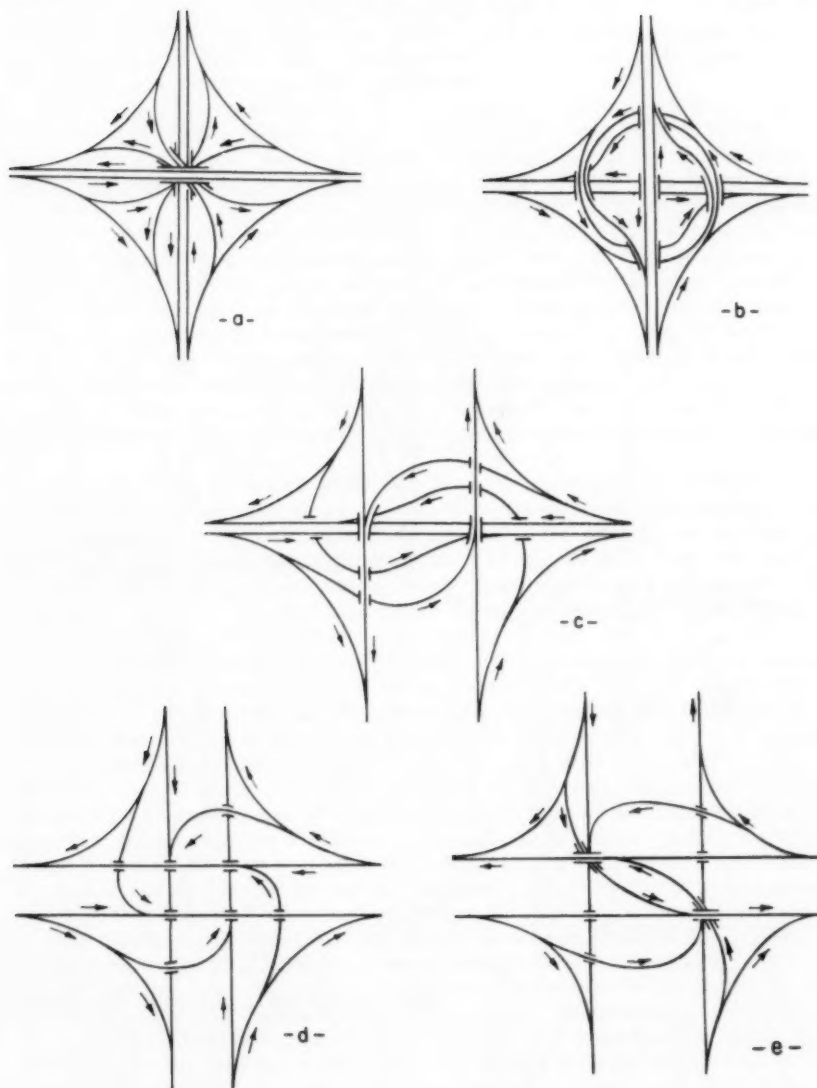
Forms of one-exit all-directional interchanges, fitting the scheme described above, are shown in Fig. 17. A variety of one-exit directional interchanges with loops, as developed in Fig. 18, also may be adaptable.

### Uniformity of Operational Pattern

On any expressway route, there are various types of interchanges, each dictated by the specific conditions at the point of intersection with the surface arterial. These interchanges, even though properly adapted, generally produce dissimilarity in the arrangement of exits between successive interchanges along the route. Although this has caused some confusion and inconvenience on our existing freeways, drivers as a whole have been able to cope with the situation. But, what about the future highways?

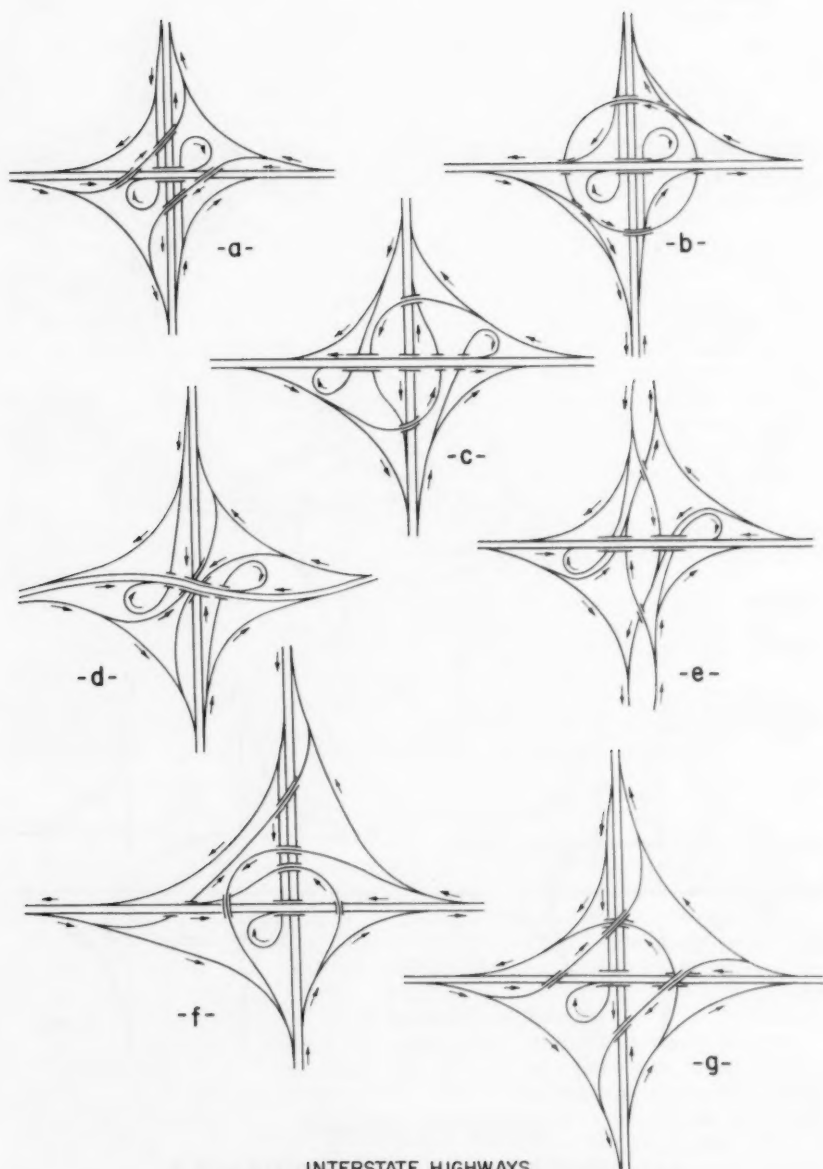
At the present time, there are not many opportunities to travel at high continuous speeds over long distances. A few years from now, as Interstate highways begin to span several states, all drivers will experience travelling on highways with such geometrics and operational features as are presently limited to the toll highways. Accordingly, the profession should not think and design in terms of what was proper in the past or what is adequate on a freeway today; but highway administrators, planners and designers must put themselves in the seats of drivers operating over a complete network of future highways having unique operational characteristics.

Measures must be taken to avoid inconsistencies in design which are apt



INTERSTATE HIGHWAYS  
ALL-DIRECTIONAL INTERCHANGES  
ONE-EXIT ARRANGEMENTS

FIGURE 17



INTERSTATE HIGHWAYS  
DIRECTIONAL INTERCHANGES  
ONE-EXIT ARRANGEMENTS WITH LOOP RAMP

FIGURE 18

to produce indecision and driving actions incompatible with the character and speed of operation. Careful design should preclude the dissimilarity in the arrangement of exits between successive interchanges which may occur with the normal use of basic forms of interchanges.

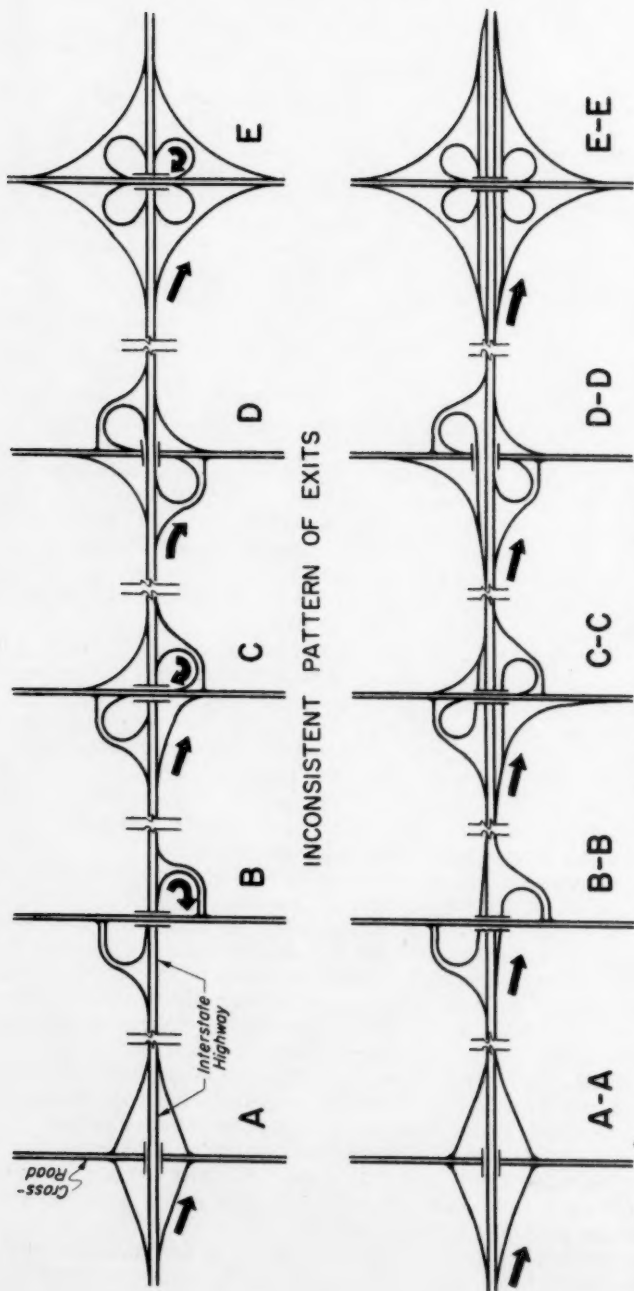
Referring to the upper part of Fig. 19, such inconsistency is quite evident. The driver is not sure where the exit will be located with respect to the crossroad, i.e., in advance of or beyond the structure. Even more serious, in one instance there may be one exit and in another there may be two exits to the same crossroad. For example, at interchange A the driver leaves at a single ramp in advance of the structure. At interchange B he makes his exit beyond the crossroad. At interchange C, to proceed south on the crossroad, the driver must use the exit in advance of the structure, but to go north he has to travel beyond the crossroad and leave via the second exit. At interchange D he reverts to a single exit. At interchange E he is again confronted with a choice between two exits. The same driver, of course, does not leave at all of these interchanges on the same trip, but any one driver may leave at a different interchange on different trips and he will have no idea which of these situations will confront him, unless a particular trip is made repeatedly.

At interchange E the cloverleaf design not only requires a realization on the part of the driver that there are two exits but an immediate decision while on the freeway as to whether his destination is to the north or to the south of the Interstate highway; further complication arises when he finds that he has to weave with traffic entering the freeway via a ramp he has just passed. This confusion takes place amidst high-speed through traffic along a facility which is supposed to be designed for a safe speed of 70 mph.

The non-repeat driver leaving the Interstate highway generally has no concept of the form of interchange at which he is to make his exit. He relies completely on directional signing. He knows the name of the locality at or near his destination; he knows the name of the crossroad or its route number. But, it is not likely that he knows, on the spur of the moment, whether his destination is to the north or to the south of the freeway. Moreover, if a place name is given on the sign, the information may be of no assistance to him unless the specific locality for which he is destined is named; in fact, the place name shown on the sign may even confuse him. Can we afford to have even an occasional bewildered driver on the through travelled way of a facility on which vehicles around him are travelling at 70 mph?

The weaving maneuvers created by the cloverleaf arrangement, also, are completely out of place along the rural sections of the Interstate system. Where vehicles are entering and leaving simultaneously on the adjoining loop ramps, the auxiliary lane has a dual function of deceleration and acceleration. As a result, leaving vehicles at times are required to decelerate on through traffic lanes and entering vehicles are forced into through traffic at a speed much below the speed of operation on the freeway. These overlapping merging and diverging maneuvers can create hazardous situations involving through traffic, even under relatively low-volume conditions. Another drawback is that the combined maneuvers of entering and leaving traffic all take place along the through travelled way within a time space of about five seconds or in a distance of not much more than 500 feet. This is hardly compatible with the 70-mph sustained speeds of through traffic.

All of these shortcomings can be readily corrected by incorporation of C-D roads into the patterns of parclo-B and cloverleaf interchanges—types B,



ARRANGEMENTS OF EXITS BETWEEN SUCCESSIVE INTERCHANGES  
INTERSTATE HIGHWAYS  
FIGURE 19

C and E in Fig. 19. The consistent arrangement, shown for the same series of interchanges in the lower part of Fig. 19, provides for operational uniformity regardless of the type of interchange. Exits in each case are always identical—one exit, on the right, in advance of the crossroad. Signs at each exit are consistently uniform, direct and simple.<sup>8</sup> The second decision, whether to go north or south, or left or right, is always made on a separate roadway, removed from the high-speed travelled way of the Interstate highway. Also, weaving maneuvers are transferred to the lower speed C-D roads, thus freeing the main travelled ways for high-speed through operation.

The restyled cloverleaf with C-D roads is now superseding the old cloverleaf along freeways in urban areas for reasons of increasing capacity and avoiding difficult weaving involving through traffic. The use of the restyled cloverleaf along turnpike-like facilities in rural areas is for quite a different reason, namely safety. Even for relatively light volumes, the very high speeds are believed to justify the uniformity and simplicity of operation achieved through the use of C-D roads.

A uniform operational pattern of exits is needed on the rural sections of the Interstate system. It does not follow that a similarly consistent pattern of exits is required on the crossroads at these same interchanges. The crossroads are part of the arterial highway network on which lower speeds prevail, and where drivers have learned to expect widely varying conditions.

The cost of introducing C-D roads to bring about operational uniformity on the freeways is relatively small. The benefits are very great, but they cannot always be computed in dollars. It is believed a full analysis would show that if, on the Interstate highway at a given crossroad, a cloverleaf interchange is justified, then its up-to-date version is always justified.

Considering the high capacity, superior quality, and maximum safety desired for this system of highways, it becomes logical and necessary to provide uniformity in operational patterns through such design features as consistency in ramp locations, even though this entails generous use of C-D roads. It is recommended, therefore, that this feature be immediately incorporated in the design of the Interstate system of highways.

## CONCLUSION

The objective in the development of this superior system of highways is clearly indicated in the AASHO standards:<sup>9</sup> “. . . In determination of all geometric features . . . a generous factor of safety shall be employed and unquestioned adequacy should be the criterion. . . . All known features of safety and utility should be incorporated in each design . . .”

To this end, the selection of the proper type of interchange at intersections with thousands of highways is the first and perhaps the most important step. In urban areas the interchange should provide adequate capacity and efficient operation, and should be sufficiently flexible to permit future expansion, if required. In rural areas interchanges should fit the character of intersecting highways and should be compatible with traffic operation on the Interstate

8. Correlation of Geometric Design and Directional Signing, by George M. Webb, Traffic Engineer, California Division of Highways—October, 1956.

9. Geometric Design Standards for the National System of Interstate and Defense Highways, AASHO, 1956.

highway at the high sustained speeds now experienced on turnpike facilities.

It has been the purpose of this paper to present the latest in geometric design techniques as they apply to interchanges on the Interstate System of Highways. The application of these techniques still requires engineering skill of the highest order. More important, improvements in interchange design will unquestionably be made as more operating experience is gained with these relatively new types of facilities. The engineers in the highway field today face a worthy challenge in finding ever better ways of designing safer and more efficient highways.

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Journal of the  
HIGHWAY DIVISION  
Proceedings of the American Society of Civil Engineers

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Note: Paper 1526 is part of the copyrighted Journal of the Highways Division, Proceedings of the American Society of Civil Engineers, Vol. 84, HW 1, January, 1958

THE [illegible] OF [illegible]

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THE HIGHWAY SPIRAL AS A CENTERLINE FOR STRUCTURES<sup>a</sup>

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Closure by Paul Hartman

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PAUL HARTMAN,<sup>1</sup> M. ASCE.—Mr. Brownfield's objection to the degree of curve is well taken. The degree system was used in this paper because it was more convenient in the derivations. It is a simple matter to change from degree to radius definition. Equation 11, the only equation involving degree of curve which is required in the method, becomes

$$\theta_s = \frac{28.6479 L}{R}$$

with L and R in feet and  $\theta_s$  in degrees. The resulting values of  $\theta$  will not be in round numbers but this will be more than compensated for by the fact that the radii of the osculating circles will be round numbers.

The alternative methods proposed by Mr. Brownfield are approximations of varying precision. They require considerably more effort to solve and would be, in the author's opinion, more difficult for the average engineer to learn and to apply.

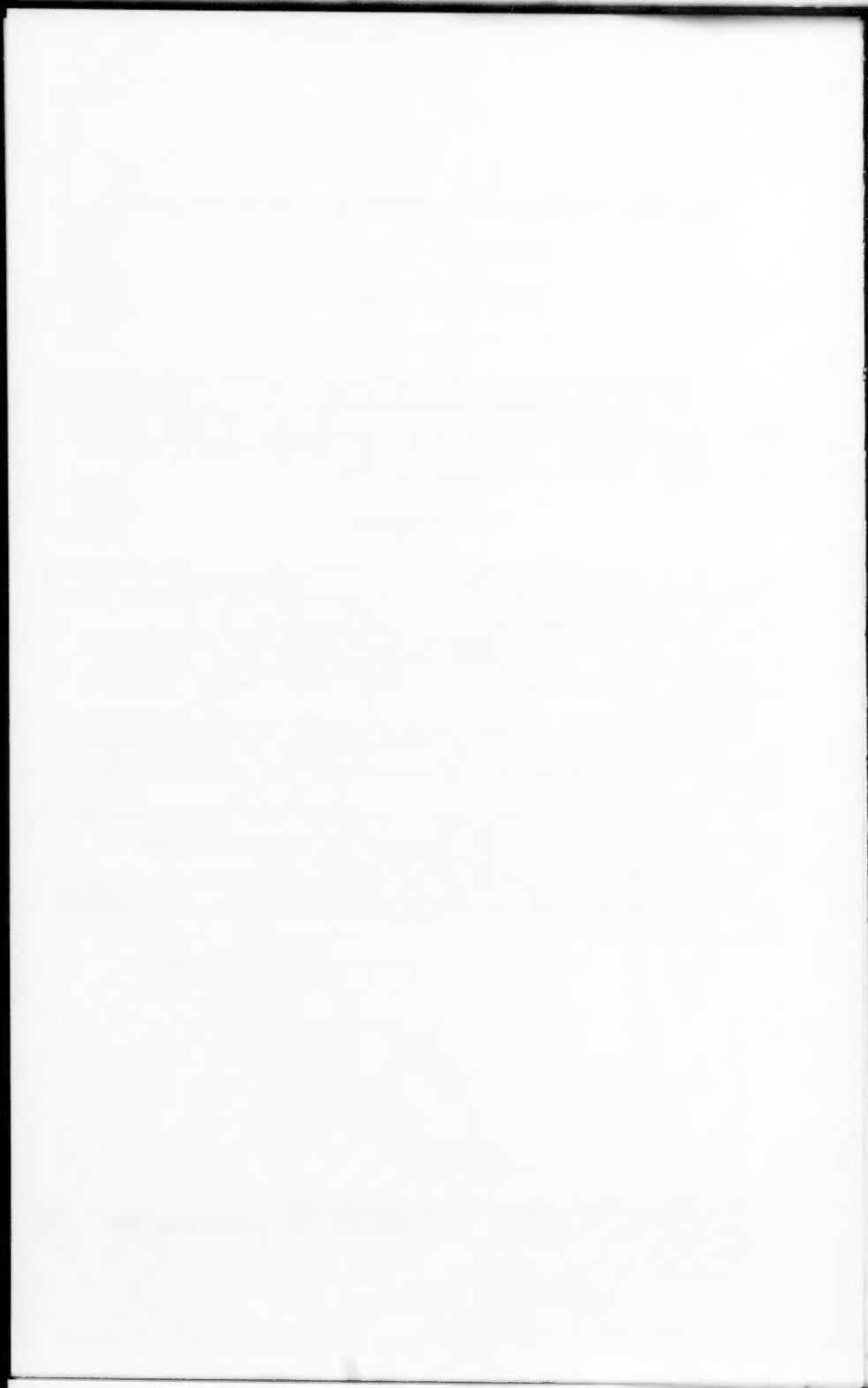
Messrs. Naughton and Villazor stress the fact that the proposed method is not precise. This is true only in that the structure may deviate as much as one-thirty-second of an inch from the concentric curve of the spiral at the outer edges of the structure.

Mr. Villazor has incorrectly stated that elements of the spiral of the illustrative problem,  $\theta_s$  is  $10^\circ$ , not  $5^\circ$ . His statement that the Y-coordinate of Point F is in error is based on his erroneous value of  $\theta_s$ .

The value of the proposed method can be determined only by using it. The writer is certain that it is a satisfactory method and believes it to be superior to any other method.

a. Proc. Paper 1090, October, 1956, by Paul Hartman.

1. Associate Prof., Dept. of Civ. Eng., College of City of New York, New York, N. Y.



THE USE OF TECHNICIANS IN HIGHWAY ENGINEERING<sup>a</sup>

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Discussion by G. I. Sawyer

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G. I. SAWYER,<sup>1</sup> M. ASCE.—It is noted that Mr. Lathrop states that more technicians are being used in the field of bridge construction and inspection to replace engineers. Although this practice may be widespread, the writer is of the opinion that if engineers can be used to carry out this type of work, the possibility of errors by the contractors is minimized. Although many of the tasks of bridge-construction inspection can be satisfactorily performed by technicians, engineers performing the same task will be in a better position to detect an engineering problem when one develops. Furthermore, contractors are not as likely to convince an engineer on a method of construction which may appear logical but lacks in engineering soundness.

For this reason, the writer advocates the use of engineers on all inspection work, if they can be recruited. What types of duties are assignable to technicians as well as engineers? For example, what kind of work do technicians perform in a bridge-engineering agency and what type of engineering does an engineer do in a road-design agency?

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a. Proc. Paper 1250, May, 1957, by Scott H. Lathrop and Francis J. Farias.

1. Chief, Planning, Design and Eng. Dept. of Highways, Washington, D. C.



DIRECT SOLUTION FOR TRIPLE SPIRALED COMPOUND CURVE<sup>a</sup>


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 Discussion by T. F. Hickerson
 

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T. F. HICKERSON,<sup>1</sup> M. ASCE.—Professor Scheer's direct solution of triple spiraled compound curves is lucid and workable for the variety of cases that might arise, and, as he states, it may readily be extended to three centered compound curves with four spirals. Also, it is good to have expressions for  $F_1$  and  $F_2$  that hold true automatically when the curve system is unsymmetrical and when there is only a simple curve ( $\phi = \text{zero}$ ) with unequal spiral lengths. For the simple curve with equal spiral lengths,  $\phi_2 = \phi_1$ , and  $F_2 = F_1 = \phi_1 \times \tan \frac{1}{2}I$ ; giving  $T_{S2} = T_{S1} = Z + \phi_1 \times \tan \frac{1}{2}I + R \tan \frac{1}{2}I = Z + (R + \phi_1) \times \tan \frac{1}{2}I$ , a well known formula.

If the layout starts with the sharper curve, the algebraic sign of the radial shift " $\phi$ " in the expressions for  $F_1$  and  $F_2$  would be negative unless the subscripts are interchanged. If  $D_1 = 2^\circ$ ,  $D_2 = 6^\circ$ ,  $L_s$  (length of combining spiral) = 400 feet,  $\phi_2 = \phi_1 = \text{zero}$ , we find  $I_1 = 4^\circ$ ,  $I_2 = 12^\circ$ ,  $I = 16^\circ$ , and the nominal spiral angle is  $8^\circ$ , from which  $\phi$  (the radial shift) = 4.652 feet. (a) Proceeding from sharper to flatter curve (left to right, say), then  $F_1$ , as measured along the tangent to the sharper curve, equals  $[-(-4.652) \cos 4^\circ] \times \csc 16^\circ = +16.836$  feet. Also,  $F_2$ , as measured along the tangent to the flatter arc, equals  $(-4.652) \times \sin 4^\circ = 16.836 \times \cos 16^\circ = -0.324 - 16.184 = -16.508$ . (b) Now, letting  $F_1$  and  $F_2$  be measured along tangents to the arcs of  $D_1$  and  $D_2$  respectively, the radial shift may be taken as positive. Thus  $F_1 = [-4.652 \times \cos 12^\circ] \times \csc 16^\circ = -16.508$ ;  $F_2 = 4.652 \times \sin 12^\circ = (-16.508) \times \cos 16^\circ = 0.9672 + 15.8685 = 16.836$ . Obviously  $F_1$  and  $F_2$  of (b) are the same as  $F_2$  and  $F_1$  of (a).

The initial and final tangents as per the unspiraled compound curve provide the best reference lines. The quantities  $F_1$  and  $F_2$  are sufficient for locating the forward (or backward) parallel tangent to the spiraled system.

Considering next the general case of a triple spiraled compound curve with a total central angle equal to  $(\theta_1 + \Delta_1 + \Delta_2 + \theta_2)$ , where part (or all) of  $\theta_1$  subtends one-half of the initial spiral (offset =  $\phi_1$ ), part (or all) of  $\theta_2$  subtends one-half of the final spiral (offset =  $\phi_2$ ), and  $(\Delta_1 + \Delta_2)$  is the total central angle of the compound curve. In this case,  $I_1 = (\theta_1 + \Delta_2)$ ,  $I_2 = (\Delta_2 + \theta_2)$ ,  $I = I_1 + I_2$ , and the formulas for  $F_1$  and  $F_2$  hold true.

Attention is called to the slight correction in  $\Delta_1$  and  $\Delta_2$  needed for accuracy in determining precise values of  $T_{S1}$  and  $T_{S2}$ , particularly for extreme

a. Proc. Paper 1372, September, 1957, by Alfred C. Scheer.

1. Formerly, Prof. of Civ. Eng., Univ. of North Carolina, Chapel Hill, N. C.

lengths of the combining spiral or layouts involving sharp curvature, because of the assumption that the spiral arc is bisected at the PCC. See SEPARATE 357 by the writer and PAPER 2867 by Hartman. The correction (called  $C_b$ ), measured in seconds, is added to  $\Delta_2$  and subtracted from  $\Delta_1$ , where  $\Delta_2$  is assumed larger than  $\Delta_1$ . The radial shift "o" found in Tables on the basis of the nominal spiral angle is also subject to a small correction, as is the deflection angle locating the final point of the combining spiral.

For the three centered compound curve with four spirals,  $F_1 = [o_4 - o_1 \cos I = o_2 \cos (I_2 + I_3) - o_3 \cos I_3] \times \csc I$ ;  $F_2$  (or what might be called  $F_3$ ) =  $o_1 \sin I + o_2 \sin (I_2 + I_3) + o_3 \sin I_3 - F_1 \cos I$ ; in which  $o_2$  and  $o_3$ , taken in order, represent the radial shifts of the intermediate circular curves.

To the writer—who happens to be preparing another edition of a book dealing with highway location and design—this paper is timely and valuable.

Referring to Fig. 2, it follows that

$$T_1 = \frac{R_1 \text{ vers } I - (R_1 - R_2) \text{ vers } I_2}{\sin I} \quad (a)$$

$$T_2 = \frac{R_2 \text{ vers } I + (R_1 - R_2) \text{ vers } I_1}{\sin I} \quad (b)$$

Now  $T_{s1} = Z_1 + T_1 + F_1$  and  $T_{s2} = Z_2 + T_2 + F_2$

Omitting for the moment the Z-terms, substituting the expressions for T and F, and replacing  $T_{s1}$  and  $T_{s2}$  with  $t_{s1}$  and  $t_{s2}$ , we have

$$t_{s1} = T_1 + F_1 = \frac{R_1 \text{ vers } I - (R_1 - R_2) \text{ vers } I_2}{\sin I} + \frac{o_2 - o_1 \cos I - o \cos I_2}{\sin I}$$

$$t_{s1} = \frac{(R_2 + o_2) - (R_1 + o_1) \cos I + (R_1 - R_2 - o) \cos I_2}{\sin I} \quad (c)$$

Similarly we get

$$t_{s2} = \frac{(R_1 + o_1) - (R_2 + o_2) \cos I - (R_1 - R_2 - o) \cos I_1}{\sin I} \quad (d)$$

In the foregoing trigonometric reductions use was made of the following identities:  $\text{versine} = 1 - \cos$ ;  $(\sin^2 I + \cos^2 I) = 1$ ;  $\cos I \cos I_2 + \sin I \sin I_2 = \cos (I - I_2) = \cos I_1$ .

It is believed that (c) and (d) will be simpler for actual calculations instead of (a) and (b) together with the expressions for  $F_1$  and  $F_2$ ; that is, it's easier to apply two longer formulas rather than four shorter ones.

SIGNIFICANCE OF TESTS FOR HIGHWAY MATERIALS<sup>a</sup>

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Discussion by E. A. Abdun-Nur

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E. A. ABDUN-NUR,<sup>1</sup> M. ASCE.—In this paper, the Committee on Significance of Tests for Highway Materials is making a very worthwhile contribution. Such a compendium, available for general distribution, has been badly needed. It probably will be useful not only to the individual young engineer as intended by the Committee, but also as material for use in group training of inspectors and junior supervisory personnel.

The following comments are made in the nature of suggestions that the Committee may want to consider in case a revision of this paper is made for future publication.

Mechanical Analysis—pages 1385-3 and 1385-4 (Typical Test Results)

The Committee on Glossary of Terms and Definitions on Soil Mechanics, of the Soil Mechanics and Foundations Division, has been working for several years with a parallel committee of the American Society for Testing Materials, and have recently agreed on a glossary of terms and definitions in the field of soil mechanics. The following definitions, applicable to this section of the paper, are quoted:

"GRAVEL - - Rounded or semirounded particles of rock that will pass a 3-inch and be retained on a No. 4 U. S. standard sieve."

"SAND - - Small particles of rock that will pass the No. 4 sieve and be retained on the No. 200 U. S. standard sieve."

"SILT - - Material passing the No. 200 U. S. standard sieve that is non-plastic or very slightly plastic and that exhibits little or no strength when air-dried."

"SILT SIZE - - This term has been used to refer to the fraction of a soil having particles between about 0.02 mm and 0.002 mm (other dimensions used in some cases)."

"CLAY - - Fine grained soil or fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and which exhibits considerable strength when air-dry. The term has been used to designate the percentage finer than 0.002 mm (0.005 in some cases), but it is strongly recommended that this usage be discontinued, since there is ample evidence that from an engineering standpoint the properties described in the above definition are many times more important."

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a. Proc. Paper 1385, September, 1957.

1. Consulting Engineer, Denver, Colorado.

"CLAY SIZE - - That portion of the soil finer than 0.002 mm (0.005 mm in some cases)."

"COLLOIDAL PARTICLES - - Soil particles that are so small that the surface activity has an appreciable influence on the properties of the aggregate."

Moisture-Density Test—page 1385-7, paragraph 5

This paragraph points out the lack of relationship between moisture and density for sandy or gravelly soils. With the increasing use of vibratory means for compacting these soils, it may be worthwhile to call attention to this means, and that the tests made by vibration do not depend on a moisture-density relationship.

Moisture-Density Test—page 1385-7, last line and succeeding page

The rigidity of the base on which the compaction test is conducted influences the results also. A box of the required height, filled with sand and covered with a piece of canvas to keep the sand from spilling makes a very effective base that gives the same results as when the compaction cylinder is placed on firm ground when compaction has to be done out in the field. Concrete bases give good results also, but the cylinder has to be mechanically tied down or it will jump off, and do not duplicate field compaction on the ground.

Moisture-Density Test—page 1385-8, second full paragraph

A caution that vibrations from rolling and hauling equipment might change this volume of the hole while the density measurement is being made, might be worthwhile.

Shear Tests—page 1385-10, first full paragraph, second sentence

Suggest insertion of "and pore pressure" after "moisture content".

Shear Tests—page 1385-11, last section

The type of test influences the results (direct shear vs. tri-axial, and method of running tri-axial also). In other words just shear test results without knowing the details of the test may not mean too much for interpretation purposes.

Consolidation Test—page 1385-12, paragraph 5

The wording is a little misleading, as in the final analysis, it is the shear test that provides the means to determine the stability, and not the consolidation. The present write-up intends to convey that meaning, but is not too clear.

Flexure Test of Concrete—page 1385-33, paragraph 1

It is very doubtful that the flexure test measures the strength of the pavement to determine proper time for opening to traffic. A beam cured by the side of the pavement will rarely if ever have the same strength as the pavement.

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Journal of the  
HIGHWAY DIVISION  
Proceedings of the American Society of Civil Engineers

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THE ADMINISTRATIVE ROLE OF THE FEDERAL GOVERNMENT  
IN THE INTERSTATE SYSTEM<sup>a</sup>

Frank C. Turner,<sup>1</sup> M. ASCE  
(Proc. Paper 1527)

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ABSTRACT

Because our 67 million motor vehicles cannot recognize the artificial political jurisdictional boundaries we have set up to subdivide 100,000,000 residents in urban areas, the author states that we must develop more effective cooperation across these boundaries if the vast highway program provided by the Federal-Aid Highway Act of 1956 is to bring needed traffic relief.

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From time immemorial transportation, the movement of people and goods, has been one of the great driving forces in human progress. And nowhere on earth has transportation been more essential to the growth and unity of a nation than here in the United States.

Our Nation's Founding Fathers were well aware of this basic truth. It is implicit in the preamble to the Constitution which proclaims the intent to form a more perfect union, provide for the common defense, and promote the general welfare. To achieve these things Article II which deals with the general powers of Congress is specific in reference to transportation, for in section 7 is included the power "To establish . . . . . post roads." Thus the legal responsibility for Federal participation in a highway program is very firmly rooted, and the guiding principles for its administration are clearly stated.

Today highway transport plays such a fundamental role in our daily lives and is such a basic factor in our economic growth that the enlarged

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Note: Discussion open until June 1, 1958. A postponement of this closing date can be obtained by writing to the ASCE Manager of Technical Publications. Paper 1527 is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. HW 1, January, 1958.

- a. Annual Convention, Highway Division Session, New York, N. Y. October 15, 1957
1. Deputy Commissioner and Chief Eng. Bureau of Public Roads, Washington, D.C.

road building program which we have undertaken may well mark the beginning of a new age for 170 million people—an age in which the motor vehicle really comes into its own as an integral factor in our American way of life. I want to point out that the Federal role in the 1956 Act Interstate System program is in no sense a new one. The 1956 Act is a direct by-product of the close and long-maintained relation between the Federal Government and our State highway departments. The bill is a fitting tribute to more than 40 years of hard work, good will, and sound experience in cooperation.

The original Federal-Aid Road Act of 1916 has left a deep and lasting imprint upon highway practices in this country. Under this early Federal law the States selected the roads to be improved, and the type of their improvement; were to be responsible for surveys, for the plans and specifications; and the making of contracts and supervision of construction. Of course, while these various steps are all subject to cooperative review by the Bureau of Public Roads the initiative still rests with the States.

Parenthetically I might say that apart from this well-defined and very effective working partnership, the Federal Government through its Bureau of Public Roads has for many years directly supervised highway improvements in our National forests and parks, Alaska, and foreign countries while also performing a large amount of highway engineering and construction for other Federal agencies.

Public Roads has long assisted a number of foreign countries in carrying out programs of highway improvement. Some of this work was undertaken through the cooperation of the International Cooperation Administration and the Export-Import Bank. Since 1930 the Bureau has assisted numerous Central American republics in the construction of the Inter-American Highway—a 3,200-mile highway link between the United States and the Panama Canal. So you see we also are an operating highway department with a program considerably larger than a majority of the individual States.

It is against this background that we must measure the enlarged role of the Federal Government under the 1956 Act. Just as a construction job this bill launched the greatest peacetime program ever undertaken. By about 1972 we expect to complete the 40,000-mile National System of Interstate and Defense Highways, linking every one of the 48 States and 90 percent of all cities with populations of 50,000 or more. For the first time Congress has authorized a long-range program designed to complete an entire highway system—the system of routes most important to the Nation.

In recent years especially the growth patterns of our society have lent new urgency to the problem. I refer, of course, to the steady trend toward regional urbanization which has become so marked in the last decade or two. Whatever name you give it, this new development is directly related to and largely dependent upon the almost universal use of motor vehicles. And because these motor vehicles recognize no artificial political jurisdictional boundaries, we must of necessity find effective ways of cooperating with each other if our transportation is to be of any real value.

That is why public officials and civil engineers alike must reckon as never before with the all-pervasive role of highway transportation. Consider the fact that today more than 100 million people are living in our central cities and metropolitan areas. The location, design, and construction of expressways and other streets and highways to serve the people living in these centers is a major civic undertaking. It calls for the cooperative efforts of civil

engineers, public officials, and business, industrial, and community leaders in every walk of life.

Consider the fact that the Interstate System alone will pass through 37 percent of all the counties in the Nation; that these counties hold over half of the rural population and market nearly half of all farm products sold; add the further fact that the Interstate System is the backbone of a Federal-aid primary network totaling 249,000 miles—not to mention a secondary system of some 521,000 miles—and you can see the absolute necessity for coordinated and careful planning which must precede the actual work of highway construction in both urban and rural areas. The location and design of paralleled and intersecting routes under the administrative jurisdiction of cities, counties, and States which lead to interchanges with the great Interstate System trunks is vitally important.

Particularly in large urban areas, the location and design of these traffic arteries touch almost every phase of urban and suburban life—the location of schools, facilities for recreation, slum clearance, and the growth and development of outlying communities.

Clearly one major role of the Federal Government lies in furnishing a means for unifying and coordinating the efforts of all the many jurisdictions which have a stake in a program aimed at providing a safer, more efficient highway transport and service. Frequently the Bureau of Public Roads will function as one member of a four-way partnership—Federal, State, county, and city, but generally only with the State.

Although the vast scope of the Interstate program will greatly increase the importance of this comparatively new four-way relationship, we are not strangers in this field. The Federal-Aid Highway Act of 1944 authorized the first specific funds for highway improvement in urban areas. Since that time the Bureau has appeared in a number of Federal-State-County-City quartets, if I may put it that way. And we have achieved, I think, some excellent harmonies.

These past performances take on added significance for the future when we remember that perhaps half of the \$25 billion authorized for the Interstate System will be spent in and around our cities to provide about 6,000 miles of arterial highways. This presents an opportunity, a challenge, and a heavy responsibility to make these highways powerful tools for city improvement.

With about half of the Interstate System program costs, as now estimated, going to urban areas it is interesting to note that anticipated Federal revenues derived from highway-user taxes will be spent in about the same proportion. This has significance for the highway user, the engineer-administrator, and all of us, for it indicates that we have set the stage for a reasonable and equitable balance in the overall construction and financial aspects of the Interstate program.

Obviously this calls for stronger working alliances and cooperative joint relations between the representatives of our Federal, State, county, and city governments than ever before. In the nature of things there are some overlapping jurisdictions and responsibilities between these representatives. But these overlaps need not lead to inefficiency and increased costs. Nor should they give rise to friction. With proper coordination; by assigning to each representative that part which he is best able to perform; there will be a complementing action which cannot fail to improve the final result.

There are some things which the Federal members of the team can do

better than the others and some which none of the others can do by themselves. Always the Federal Government has given to the States the right to initiate, reserving to itself only the right to approve the States' proposals when Federal funds are requested. Over the years differences of opinion and approach have arisen, as rightly they should in a full partnership, but it is highly significant and a tribute to both parties that these differences have always been resolved in the best professional traditions—and with a final resultant that has generally stood the test of critical analysis by both parties.

This is one important role of the Bureau. In the professional give and take of these exchanges we also develop a well-documented public record. This kind of procedure certainly does not imply any monopoly of knowledge or ability. To the contrary, it is simply a built-in device which we have developed for putting our product—a better highway—through its own proving-ground trials before it is sold on the public market. The many problems, new and old, arising out of the Interstate program in all areas will demand even more extensive use of this checking procedure in the future.

You may not know it but the definition of an urban area in the Federal-Aid Highway Act does not mention the usual city limits term. This is quite intentional because the highway program is related to land use and development patterns and not to artificial political jurisdictional boundaries. Indeed, the automobile and its driver seldom know or care about such boundaries—except as they may interfere with the availability of a continuous highway roadbed and the easy flow of traffic which it provides. This means then that for efficient use of our motor transportation we must find means of being able to build uninterruptedly across these political boundaries, whether they be State, city, county, town, or township lines. When our country was young and transportation slower with range of movement small, these boundary lines had little effect because the normal movement of individuals was generally confined wholly within some one such unit. But in a few minutes today millions of our daily trips cross several such boundary lines, mostly city limits boundaries, but often State lines as well. Take the daily commuting pattern of New York, Chicago, St. Louis, Kansas City, Philadelphia, Washington, or many others as examples. Any single day's trip from home to business place and return will probably cross half a dozen such lines each way. It is unthinkable that there should be anything but coordinated planning and cooperative effort in solving our urban highway problems under such conditions.

We have done reasonably well, but I do not think we have yet done as well as ultimately—and quickly—we must do if we are efficiently and economically to provide the public with facilities which they have been told to expect and for which they have given us in the highway field the go-ahead signal; complete with funds, incidentally. We therefore have a compelling directive to find an answer to this problem. It is a problem, however, only if we do nothing about it—there is an answer and a solution.

While I personally feel sure that that answer is ultimately in the political field and therefore outside our engineering formulas, there are some things we can do short of that step and while waiting for it to occur. We hear much of such plans as "metros", and consolidation of city and county governments, and other devices, all of which I predict will gradually become widespread and accepted everywhere. These involve a change in our political philosophies, however, and such a change is necessarily—and properly—a slow one. In other words, the evolution of new concepts for our forms of local

governments where counties and cities or a cluster of numerous small cities abut on each other to form a metropolitan or urban area. You can see therefore that our Federal-aid highway Acts—going back to 1944—already contain the concept of urban areas—related to metropolitan land uses—rather than those artificial boundary lines called city limits.

But we have a problem to resolve now—in 1957 and 1958—not in the sometimes of the future. The solution lies in voluntary joint cooperation of our several political jurisdictions—county, city, State, and Federal. We are already doing this in many cases—in most, I would say—closer coordination is needed even yet. The day when Federal-aid funds could be expended only in rural areas is long since past—more than 20 years to be exact—since the law was amended to provide funds which could be used to ease the urban area traffic problem. Likewise, the day is long past when a State highway department could drop its load of State highway traffic at the city limit sign without a care as to what would happen on the other side. In similar fashion, the city and the county can no longer think and build in their own separated and individual little compartments without knowledge of or consideration for what the traffic picture is around about them. Cooperation, coordination, and also consolidation in many instances is the obvious need.

What are we doing toward this end? Discussions and studies like this very panel which will stimulate creative thinking on the matter are a part. The Bureau has just recently initiated with county officials and some other interested agencies, such as the Automotive Safety Foundation, a research project on county highway management, looking toward how this unit of local government can most efficiently discharge its highway responsibilities in the fast-moving, complex, and expensive highway transport system picture of today and tomorrow. The Bureau, the American Municipal Association, and the American Association of State Highway Officials have recently joined in the formation of a new AMA-AASHO joint committee to assist in providing a coordinating mechanism in the urban area-State highway department field. So you can see that we are taking some concrete steps toward reaching answers to these questions while the slow processes of political change are awakening.

I have stressed the unifying, coordinating role of the Federal Government in highway improvement because I believe it to be the Bureau's most significant and long-lasting contribution to our growth and unity as a free Nation.

Since the Interstate System serves more than 90 percent of all our cities of more than 50,000 population, and all of our industrial cities of more than 100,000 population, it becomes self-evident that when talking about the Interstate System in urban areas, it becomes a matter of interest to every city which is of such a size as to begin to have an urban problem of the kind we are discussing here.

The Interstate System particularly in the urban areas will weave the pattern and build the framework on which virtually every future element of growth and development in our urban areas will be dependent, both private and public, and with such staggering impact, felt over a long period of time, it is imperative that we as engineers who plan and approve the plans exercise the utmost of good judgment and the maximum of ability if the public is to be insured of the best final result.

In this our Federal role is one of coordination of State with State, planner with builder, Congressman and the citizen—to the end that we shall be able to translate the pennies paid by the individual road user into an Interstate

System which is truly national in scope, yet characterized by an ability to serve a majority of the individual motorists' personalized travel needs. The Federal Government must do this while at no time usurping the basic principle of initiative by the States and local self-government. This is a large order, but there is no reason to fear that we shall fail to achieve it, because we are in fact already doing it in a well-formed routine and accepted manner. We must merely enlarge and strengthen. The Bureau's position therein must be essentially that of coordinator of the four-part partnership, leader of those States in the forefront, pusher for the various partners that are lagging, an enforcer of standards, an arbiter of national interest questions, a collector of the pennies, and disburser of the billions. We must serve as a clearing house for new ideas, and improved versions of the old; the principal exponent, leader, and collector of vital research in the highway field; the buffer with Congress; and the executive custodian of a Constitutionally declared national interest in highways.

In this respect, I believe the Bureau role is clear and the responsibility rather staggering. The one single national characteristic of our country is our national unity. We wander as tourists or businessmen over our entire country as easily as going across our home towns, with never a fear nor a thought but that we still are "at home." It is the unity of our media of transportation and communications which makes this possible in such a "take-it-for-granted" manner. In this our highways play perhaps the major role. To do so, however, they must of necessity be one fully integrated, coordinated, and unified network rather than a series of separate systems lacking a national oneness. The welding flux in this instance is the Bureau—to see that from the highway standpoint our country is truly and in fact a United States. This is, I believe, the Bureau's part in the common effort and goal.



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# PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1449 is identified as 1449 (HY 6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1957.

## VOLUME 83 (1957)

JANUARY: 1136(CP1), 1137(CP1), 1138(EM1), 1139(EM1), 1140(EM1), 1141(EM1), 1142(SM1), 1143(SM1), 1144(SM1), 1145(SM1), 1146(ST1), 1147(ST1), 1148(ST1), 1149(ST1), 1150(ST1), 1151(ST1), 1152(CP1)<sup>c</sup>, 1153(HW1), 1154(EM1)<sup>c</sup>, 1155(SM1)<sup>c</sup>, 1156(ST1)<sup>c</sup>, 1157(EM1), 1158(EM1), 1159(SM1), 1160(SM1), 1161(SM1).

FEBRUARY: 1162(HY1), 1163(HY1), 1164(HY1), 1165(HY1), 1166(HY1), 1167(HY1), 1168(SA1), 1169(SA1), 1170(SA1), 1171(SA1), 1172(SA1), 1173(SA1), 1174(SA1), 1175(SA1), 1176(SA1), 1177(HY1)<sup>c</sup>, 1178(SA1), 1179(SA1), 1180(SA1), 1181(SA1), 1182(PO1), 1183(PO1), 1184(PO1), 1185(PO1)<sup>c</sup>.

MARCH: 1186(ST2), 1187(ST2), 1188(ST2), 1189(ST2), 1190(ST2), 1191(ST2), 1192(ST2)<sup>c</sup>, 1193(PL1), 1194(PL1), 1195(PL1).

APRIL: 1196(EM2), 1197(HY2), 1198(HY2), 1199(HY2), 1200(HY2), 1201(HY2), 1202(HY2), 1203(SA2), 1204(SM2), 1205(SM2), 1206(SM2), 1207(SM2), 1208(WW1), 1209(WW1), 1210(WW1), 1211(WW1), 1212(EM2), 1213(EM2), 1214(EM2), 1215(PO2), 1216(PO2), 1217(PO2), 1218(SA2), 1219(SA2), 1220(SA2), 1221(SA2), 1222(SA2), 1223(SA2), 1224(SA2), 1225(PO)<sup>c</sup>, 1226(WW1)<sup>c</sup>, 1227(SA2)<sup>c</sup>, 1228(SM2)<sup>c</sup>, 1229(EM2)<sup>c</sup>, 1230(HY2)<sup>c</sup>.

MAY: 1231(ST3), 1232(ST3), 1233(ST3), 1234(ST3), 1235(IR1), 1236(IR1), 1237(WW2), 1238(WW2), 1239(WW2), 1240(WW2), 1241(WW2), 1242(WW2), 1243(WW2), 1244(HW2), 1245(HW2), 1246(HW2), 1247(HW2), 1248(WW2), 1249(HW2), 1250(HW2), 1251(WW2), 1252(WW2), 1253(IR1), 1254(ST3), 1255(ST3), 1256(HW2), 1257(IR1)<sup>c</sup>, 1258(HW2)<sup>c</sup>, 1259(ST3)<sup>c</sup>.

JUNE: 1260(HY3), 1261(HY3), 1262(HY3), 1263(HY3), 1264(HY3), 1265(HY3), 1266(HY3), 1267(PO3), 1268(PO3), 1269(SA3), 1270(SA3), 1271(SA3), 1272(SA3), 1273(SA3), 1274(SA3), 1275(SA3), 1276(SA3), 1277(HY3), 1278(HY3), 1279(PL2), 1280(PL2), 1281(PL2), 1282(SA3), 1283(HY3)<sup>c</sup>, 1284(PO3), 1285(PO3), 1286(PO3), 1287(PO3)<sup>c</sup>, 1288(SA3)<sup>c</sup>.

JULY: 1289(SM3), 1290(EM3), 1291(EM3), 1292(EM3), 1293(EM3), 1294(HW3), 1295(HW3), 1296(HW3), 1297(HW3), 1298(HW3), 1299(SM3), 1300(SM3), 1301(SM3), 1302(ST4), 1303(ST4), 1304(ST4), 1305(SU1), 1306(SU1), 1307(SU1), 1308(ST4), 1309(SM3), 1310(SU1)<sup>c</sup>, 1311(EM3)<sup>c</sup>, 1312(ST4), 1313(ST4), 1314(ST4), 1315(ST4), 1316(ST4), 1317(ST4), 1318(ST4), 1319(SM3)<sup>c</sup>, 1320(ST4), 1321(ST4), 1322(EM3), 1323(AT1), 1324(AT1), 1325(AT1), 1326(AT1), 1327(AT1), 1328(AT1)<sup>c</sup>, 1329(ST4)<sup>c</sup>.

AUGUST: 1330(HY4), 1331(HY4), 1332(HY4), 1333(SA4), 1334(SA4), 1335(SA4), 1336(SA4), 1337(SA4), 1338(SA4), 1339(CO1), 1340(CO1), 1341(CO1), 1342(CO1), 1343(CO1), 1344(PO4), 1345(HY4), 1346(PO4)<sup>c</sup>, 1347(BD1), 1348(HY4)<sup>c</sup>, 1349(SA4)<sup>c</sup>, 1350(PO4), 1351(PO4).

SEPTEMBER: 1352(IR2), 1353(ST5), 1354(ST5), 1355(ST5), 1356(ST5), 1357(ST5), 1358(ST5), 1359(IR2), 1360(IR2), 1361(ST5), 1362(IR2), 1363(IR2), 1364(IR2), 1365(WW3), 1366(WW3), 1367(WW3), 1368(WW3), 1369(WW3), 1370(WW3), 1371(HW4), 1372(HW4), 1373(HW4), 1374(HW4), 1375(PL3), 1376(PL3), 1377(IR2)<sup>c</sup>, 1378(HW4)<sup>c</sup>, 1379(IR2), 1380(HW4), 1381(WW3)<sup>c</sup>, 1382(ST5)<sup>c</sup>, 1383(PL3)<sup>c</sup>, 1384(IR2), 1385(HW4), 1386(HW4).

OCTOBER: 1387(CP2), 1388(CP2), 1389(EM4), 1390(EM4), 1391(HY5), 1392(HY5), 1393(HY5), 1394(HY5), 1395(HY5), 1396(PO5), 1397(PO5), 1398(PO5), 1399(EM4), 1400(SA5), 1401(HY5), 1402(HY5), 1403(HY5), 1404(HY5), 1405(HY5), 1406(HY5), 1407(SA5), 1408(SA5), 1409(SA5), 1410(SA5), 1411(SA5), 1412(EM4), 1413(EM4), 1414(PO5), 1415(EM4)<sup>c</sup>, 1416(PO5)<sup>c</sup>, 1417(HY5)<sup>c</sup>, 1418(EM4), 1419(PO5), 1420(PO5), 1421(PO5), 1422(SA5)<sup>c</sup>, 1423(SA5), 1424(EM4), 1425(CP2).

NOVEMBER: 1426(SM4), 1427(SM4), 1428(SM4), 1429(SM4), 1430(SM4)<sup>c</sup>, 1431(ST6), 1432(ST6), 1433(ST6), 1434(ST6), 1435(ST6), 1436(ST6), 1437(ST6), 1438(SM4), 1439(SM4), 1440(ST6), 1441(ST6), 1442(ST6)<sup>c</sup>, 1443(SU2), 1444(SU2), 1445(SU2), 1446(SU2), 1447(SU2), 1448(SU2)<sup>c</sup>.

DECEMBER: 1449(HY6), 1450(HY6), 1451(HY6), 1452(HY6), 1453(HY6), 1454(HY6), 1455(HY6), 1456(HY6)<sup>c</sup>, 1457(PO6), 1458(PO6), 1459(PO6), 1460(PO6)<sup>c</sup>, 1461(SA6), 1462(SA6), 1463(SA6), 1464(SA6), 1465(SA6), 1466(SA6)<sup>c</sup>, 1467(AT2), 1468(AT2), 1469(AT2), 1470(AT2), 1471(AT2), 1472(AT2), 1473(AT2), 1474(AT2), 1475(AT2), 1476(AT2), 1477(AT2), 1478(AT2), 1479(AT2), 1480(AT2), 1481(AT2), 1482(AT2), 1483(AT2), 1484(AT2), 1485(AT2)<sup>c</sup>, 1486(BD2), 1487(BD2), 1488(PO6), 1489(PO6), 1490(BD2), 1491(BD2), 1492(HY6), 1493(BD2).

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JANUARY: 1494(EM1), 1495(EM1), 1496(EM1), 1497(IR1), 1498(IR1), 1499(IR1), 1500(IR1), 1501(IR1), 1502(IR1), 1503(IR1), 1504(IR1), 1505(IR1), 1507(IR1), 1508(ST1), 1509(ST1), 1510(ST1), 1511(ST1), 1512(ST1), 1513(WW1), 1514(WW1), 1515(WW1), 1516(WW1), 1517(WW1), 1518(WW1), 1519(ST1), 1520(EM1)<sup>c</sup>, 1521(PO1)<sup>c</sup>, 1522(ST1)<sup>c</sup>, 1523(WW1)<sup>c</sup>, 1524(HW1), 1525(HW1), 1526(HW1)<sup>c</sup>, 1527(HW1).

c. Discussion of several papers, grouped by Divisions.

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